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RESPONSE ACTION PLAN
SLURRY WALL AND
INERT AREA CAP DESIGN AND
SLURRY WALL CONSTRUCTION

DELAWARE SAND & GRAVEL SITE
NEW CASTLE, DELAWARE

SEPTEMBER 30, 1992

Prepared for:

Delaware Sand & Gravel Site Technical Committee

Prepared by:

McLaren/Hart Environmental Engineering Corporation
200 Stevens Drive, Suite 300
Lester, PA 19113

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1.0 INTRODUCTION AND OVERVIEW

1.1 PURPOSE AND OBJECTIVES

This Response Action Plan (RAP) has been prepared to fulfill the requirements of the Administrative Order by Consent (Consent Order) bearing Index No. III-92-24-DC, dated June 19, 1992 and the Statement of Work (SOW) appended as an Appendix to the Consent Order for the Delaware Sand and Gravel (DS&G) Site in New Castle, Delaware, issued by U.S.EPA pursuant to Section 106(a) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended, 42 U.S.C. §9606(a). This RAP is submitted on behalf of the Delaware Sand and Gravel Site Technical Committee (Committee) which includes certain Respondents of the Consent Order. The RAP has been prepared in general accordance with the U.S.EPA document entitled, "Superfund Remedial Design and Remedial Action Guidance" (OSWER Directive 9355.0-4A, June 1986) and in a manner consistent with the National Contingency Plan (NCP).

The RAP describes the work to be performed under this Consent Order which is planned to address potential migration of Site contaminants on an interim basis until a permanent remedy can be selected and implemented for the Delaware Sand and Gravel Site. As described in greater detail throughout the RAP, the work to be performed under the Consent Order includes the following basic elements:

- Construct a slurry wall around the Drum Disposal Area to prevent hazardous substances from migrating from the Drum Disposal Area to the Upper Potomac Aquifer, hereafter referred to as the "Slurry Wall";

- Operation and Maintenance ("O&M") of the Slurry Wall; and

- Design a multi-layered cap for the Inert Area.

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The objective of this RAP is to set forth detailed plans, procedures, methods and schedules for obtaining needed design information and data to design and construct the slurry wall around the Drum Disposal Area and design the Inert Area cap.

1.2 SITE DESCRIPTION AND HISTORY

The Delaware Sand and Gravel (DS&G) Site consists of approximately 27 acres located on Grantham Lane, about 2 miles southwest of the town center of New Castle, New Castle County, Delaware. From approximately 1963 through 1976, hazardous substances were disposed of at the Site. The site contains at least four areas where hazardous substances have been disposed: the Drum Disposal Area, Inert Disposal Area, Ridge Area, and Grantham South Area. Army Creek, a tributary of the Delaware River, borders the Site to the north and west. This RAP focuses on the Drum Disposal and Inert Areas. A map of the site, showing the Drum Disposal and Inert Areas, is included as Figure 1-1.

On or about September 9, 1968, the Delaware Water and Air Resource Commission issued to the Delaware Sand and Gravel Company, the owner and operator of the Site, a Certificate of Approval for a sanitary landfill which allowed for the disposal of cardboard, wire, pallets, corkdust, and styrofoam in the solid waste landfill.

During 1970, the Delaware Department of Natural Resources and Environmental Control (DNREC) issued a Solid Waste Disposal Permit for continued operation of the Site as a solid waste landfill, effective from 1971 to 1976.

DNREC inspected the Site during 1975 and installed groundwater monitoring wells around the site because DNREC suspected that leachate from the landfill had impacted the groundwater. Due to improper operating procedures at the Site, which included poor cover and compaction of the disposed materials on site, DNREC took a civil enforcement action against the Delaware Sand and Gravel Company during 1976 which resulted in the closure of the landfill.

During 1987, DNREC suspected that an estimated 7,500 drums containing industrial liquids and sludges from perfume, plastic, paint, and petroleum refining processes had been emptied into

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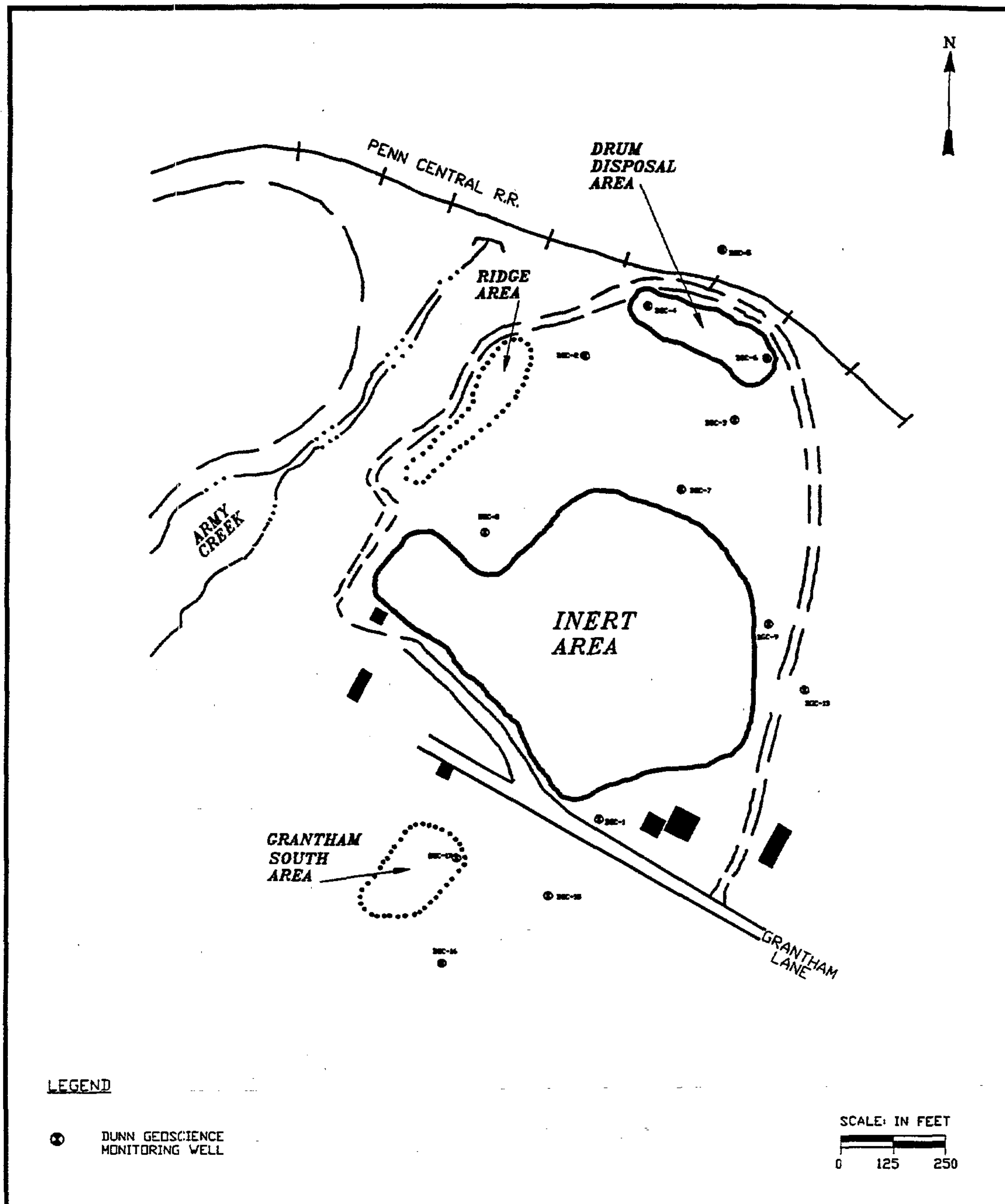

McLaren Hart McLAREN/HART ENVIRONMENTAL ENGINEERING CORP. LESTER, PA	SITE MAP DELAWARE SAND & GRAVEL NEW CASTLE, DELAWARE DATE: 7-30-92 APP'D: J.W. DRAWING NO. FIGURE 1-1

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an unlined pit of approximately 3/4 of an acre in size and approximately 15 feet deep at the Site. This unlined pit became known as the Drum Disposal Area (DDA).

The Site was proposed for listing on the National Priorities List (NPL) in October 1981. Pursuant to Section 105 of CERCLA 42 U.S.C § 9605, U.S.EPA placed the Site on the NPL, set forth at 40 C.F.R. Part 300, Appendix B, by publication in the Federal Register on September 8, 1983 (48 Fed. Reg. 40658).

During December 1983, a Superfund Site Investigation (SI) was performed by U.S.EPA. Based on the results of the SI, U.S.EPA initiated a removal action in the Drum Disposal Area during March 1984. As part of the removal action, 1,644 drums, many of which were intact, were recovered and disposed of by U.S.EPA. The remaining drums were covered with topsoil and hydroseeded. A fence was then constructed around the perimeter to restrict unauthorized access to the Drum Disposal Area.

On April 22, 1988, a ROD was finalized for the Site.

On or about July 30, 1991 the U.S.EPA Region III Removal Branch performed an inspection of the Drum Disposal Area. U.S.EPA inspectors observed that the fence surrounding the Drum Disposal Area had been breached and that tire tracks from recreational vehicles were on top of the pit which indicated that unauthorized entry had been made into the Drum Disposal Area. Several seeps were also observed on top of the Drum Disposal Area.

On October 18, 1991, U.S.EPA issued an Administrative Order (Docket No. III-91-71-DC) pursuant to Section 106(a) of CERCLA, to Respondents which required the Respondents to construct a fence around the Drum Disposal Area to preclude access to the Drum Disposal Area. The fence was constructed by Respondents within the time frames specified in the Order. The fence which had been constructed by U.S.EPA in 1983 around the perimeter of the Drum Disposal Area had been breached and broken apart by trespassers and wildlife.

U.S.EPA is currently completing a Superfund remedial pre-design investigation of the Site. To date, the pre-design investigation has been undertaken at the Drum Disposal Area in two stages.

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During the summer of 1990 Stage One of the investigation was performed by U.S.EPA and included a magnetometer survey of the Drum Disposal Area to delineate the boundaries of the drum burial area, the excavation of six test pits at the perimeter of the Drum Disposal Area, and soil boring exploration at the perimeter of the Drum Disposal Area. The purpose of Stage One of the investigation was to define the horizontal and vertical extent of contamination in the Drum Disposal Area, and to determine the condition and the estimated quantity of wastes from drums in the Drum Disposal Area.

During Stage One of the pre-design investigation, six test pits were excavated at the perimeter of the Drum Disposal Area to further delineate the boundaries of the Drum Disposal Area. Buried, intact drums were found in these test pits at depths up to 15 feet. Twenty-three soil borings were planned for the perimeter and interior of the Drum Disposal Area in order to determine the horizontal and vertical extent of contamination. Eight soil borings were drilled around the perimeter of the Drum Disposal Area with the remaining 15 soil borings planned for the interior of the Drum Disposal Area. The 15 interior soil borings were canceled, due to safety concerns, when intact drums were encountered during the test pit excavation. As a result, the 15 borings planned for the interior were placed around the perimeter of the Drum Disposal Area along with the eight borings originally planned for the perimeter. It had previously been considered feasible to extend borings into the Drum Disposal Area without drum removal, because of the reported piercing and draining of these drums prior to disposal, making the likelihood of finding intact waste containing drums remote. However, the discovery of intact drums in the test pits rendered any soil boring exploration in the Drum Disposal Area a safety hazard.

Laboratory analysis of the perimeter test pit and boring samples detected elevated concentrations of methylene chloride, toluene, xylene, ethylbenzene, chloroform, styrene, trichloroethene and PCBs. Other volatile and semi-volatile compounds were also detected.

The wastes in the Drum Disposal Area are currently located in what is geologically known ~~at~~ as the Columbia Formation. The Columbia Formation is comprised of sandy silts, silty sands, and fine to coarse-grain sand with varying amounts of silt, clay, and pea-sized gravels. During Stage One of the pre-design investigation, approximately 3.7 feet of fluid was discovered in the

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Drum Disposal Area above the Upper Potomac Clay Layer. The Upper Potomac Clay Layer rests beneath the Drum Disposal Area and the Columbia Formation.

Based on the results of the Stage One Investigation, Stage Two of the pre-design investigation was modified to include the excavation of two trenches, to create two drum-free areas into which borings could safely be extended to characterize the soils and wastes beneath the drums in the Drum Disposal Area. Stage Two activities were performed during January and February of 1991.

During Stage Two of the pre-design investigation, two trenches were extended from the perimeter of the Drum Disposal Area to approximately 30 feet into the Drum Disposal Area. Sixty-four (64) intact or waste-containing drums were removed. Additional drums were to be removed at that time but trenching was stopped when the depth of water encountered in the excavation area made it difficult to proceed further. All sixty-four (64) drums were placed into overpack containers to contain any leakage from the drums. Of the sixty-four (64) overpacked, twenty (20) had to be overpacked into special overpacks to accommodate badly warped drums. During the trenching, rusted and leaking drums were encountered one to two feet below the surface and down to a depth of fifteen (15) feet. Many laboratory packs were found within buried, partially open drums. Leaking of drum contents was evident as indicated by stained soils. Upon completion of the trenching, drum removal, and trench sampling activities, the trenches were backfilled with clean fill.

It is evident from borings drilled during the pre-design investigation beneath and along the perimeter of the Drum Disposal Area that fluids from the pit area are leaching through the Columbia Formation sediments to the top of the relatively impermeable clay unit which caps the underlying Potomac Clay Formation. The fluids then move horizontally (sheet flow) on top of the Potomac Clay unit discharging through a zero clay area into the Upper Potomac aquifer.

During July 1991, McLaren/Hart working for the Committee, sampled thirty-three (33) of the sixty-four (64) drums which had been staged at the Site by U.S.EPA during Stage Two of the pre-design investigation. Thirty-four samples were taken and analyzed for volatile organic compounds, semi-volatile organic compounds, metals, pesticides, and PCBs. Major substances

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of concern which were detected include: methylene chloride, naphthalene, toluene, benzene, 2-butanone (MEK), ethylbenzene, styrene, phenol, and Aroclor-1254.

Based on the information described above, U.S.EPA determined on or about March 22, 1992, that a threat to public health or welfare or the environment exists at the Site and that a removal action is warranted. Following this determination, the Respondents received the Consent Order from U.S.EPA to construct a slurry wall around the DDA and to design a multi-layered cap for the Inert Area.

1.3 SUMMARY OF RESPONSE ACTION PLAN

This Response Action Plan for implementation of the work specified in paragraph 8.3 and the attached Statement of Work to the Consent Order, is prepared for the Inert Area cap design and the Drum Disposal Area slurry wall design and slurry wall construction. In order to conduct the Response Action in an expeditious and cost-effective manner, several U.S.EPA guidance documents are particularly applicable. These guidance documents are:

- Superfund Remedial Design and Remedial Action Guidance (June, 1986);
- Guidance on Oversight of PRP Performed RD/RA (February, 1990);
- Quality Assurance/Quality Control Guidance for Removal Activities (April, 1990); ~~and~~
- Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans (December 1980);
- Final Covers on Hazardous Waste Landfills and Surface Impoundments (July 1989); and
- Slurry Trench Construction for Pollution Migration Control (February 1984).

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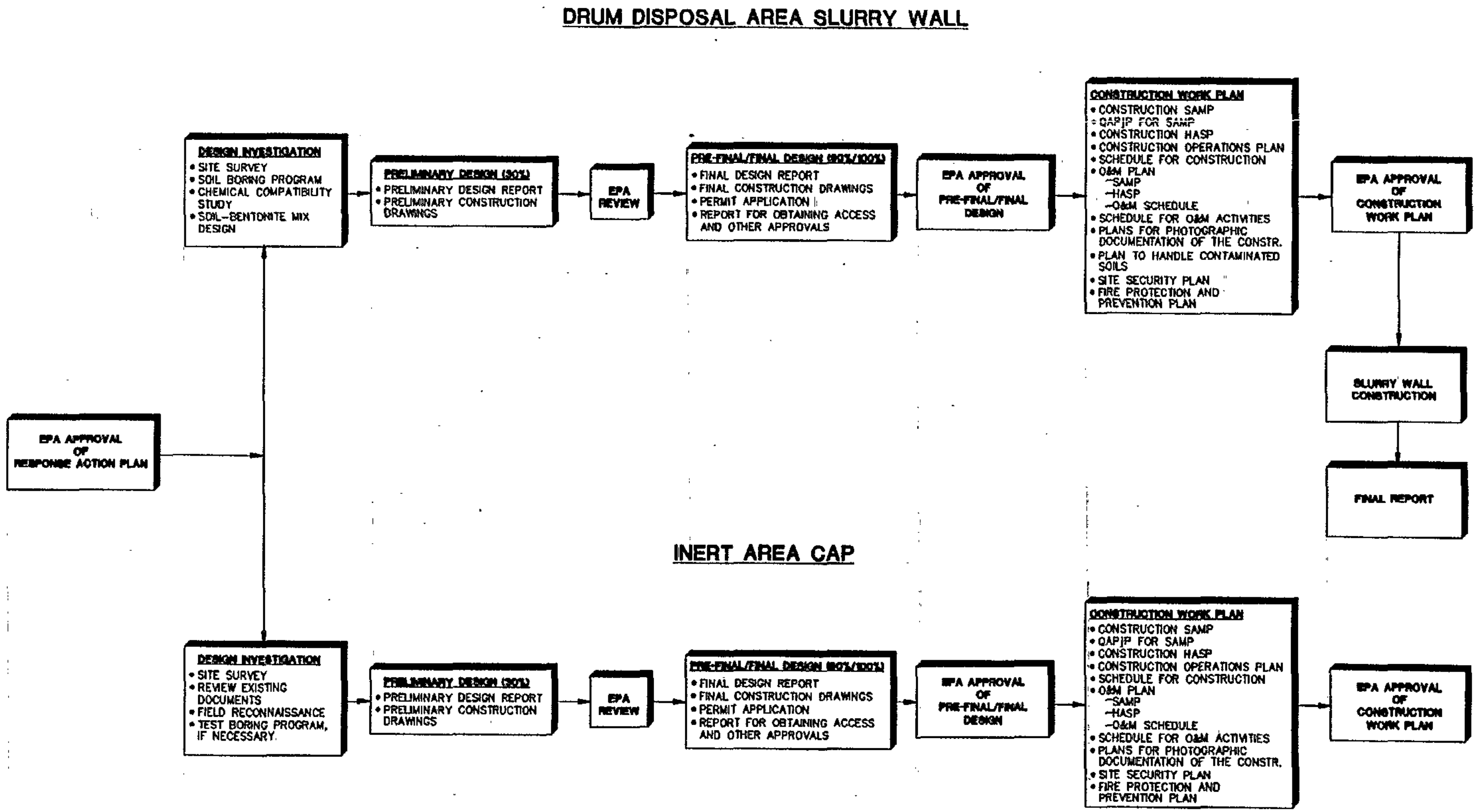
This RAP includes a number of specific components required by the SOW. The organization and presentation of the various components follows the order as follows:

- Slurry Wall and Inert Area Cap Design Investigation (Section 2)
  - Sampling, Analysis and Monitoring Plan (SAMP), including the Field Sampling Plan (FSP), a Quality Assurance Project Plan (QAPjP), and a Health and Safety Plan (HASP);
- Slurry Wall and Inert Area Cap Design (Section 3); and
- Project Schedules (Section 4).

Figure 1-2 presents a task flow diagram for the works to be performed as outlined in this Response Action Plan. In the following sections, each element of this Response Action Plan is described in greater detail.



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McLAREN/HART
ENVIRONMENTAL ENGINEERING CORP.
LESTER, PA

RESPONSE ACTION TASK FLOW DIGRAM
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

DATE: 7-30-92
APP'D: J.W.

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FIGURE 1-2

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2.0 SLURRY WALL AND INERT AREA CAP DESIGN INVESTIGATION

Several design investigation tasks will be conducted to supplement the existing data prior to completing the Slurry Wall and Inert Area cap designs. The tasks described in the following subsections will provide additional details necessary to implement the response actions.

2.1 SITE SURVEY

At the start of the design investigation, an updated Site survey, including a detailed topographic survey will be performed to provide the information necessary to design the Slurry Wall and the Inert Area Cap. Procedures for conducting the site survey are discussed in Section 2.4.1 - Field Sampling Plan.

2.2 GEOTECHNICAL INVESTIGATIONS AND TESTING FOR SLURRY WALL

Geotechnical investigations and/or tests to be completed prior to the design of the Drum Disposal Area slurry wall are a soil boring program, a chemical compatibility study and a soil-bentonite mix design test. The general scope of work and data objectives for each of these Slurry Wall action tasks are briefly described in the following paragraphs. Detailed descriptions of the geotechnical field investigations are provided in Section 2.4 - Sampling, Analysis and Monitoring Plan.

2.2.1 Drum Disposal Area Soil Boring Program

During McLaren/Hart's site investigation of June through August 1991, large numbers of soil samples were collected from soil boring series MHB and CB, and monitoring well cluster MHW-1. These samples were analyzed for both organic and inorganic parameters. The analytical results were presented in Appendix A1 of the October 17, 1991 report entitled, "Drum Disposal Area - Remedial Action Evaluation." In general, the soil samples from the MHB series and well cluster MHW-1 had relatively high organic concentrations, and the soil samples from all CB series borings showed either very low concentrations or non-detectable levels for all volatile and semi-volatile organic parameters or analyses. Based on these analytical results, best

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engineering judgement and the physical constraint of the Penn Central Railroad tracks, the alignment of the slurry wall was determined as shown in Figure 2-1.

A soil boring program will be completed around the perimeter of the Drum Disposal Area along the proposed alignment of the slurry wall. The primary objectives of the soil boring program include:

- Determining the depth to the top of the Potomac Confining Layer;
- Providing a more detailed characterization of site geology;
- Collecting samples for grain-size analysis; and
- Collecting bulk soil samples to be used for selecting the appropriate soil-bentonite mixture for the slurry wall construction.

A description of the field procedures and sampling protocols to be used for the soil boring program is described in Section 2.4.1 - Field Sampling Plan.

2.2.2 Chemical Compatibility Study

A major concern in the application of a bentonite slurry wall to site remediation is the compatibility of the soil-bentonite backfill mixture with site-specific contaminants. The available literature indicates that soil-bentonite backfills are not able to withstand attack by strong acids and bases, strong salt solutions, and some organic compounds.

Based on a limited review of the existing information, it is indicated that the Site contaminants are compatible with the soil-bentonite backfill mixture. In order to confirm that the Site contaminants will not effect the backfill permeability, a literature search will be conducted.

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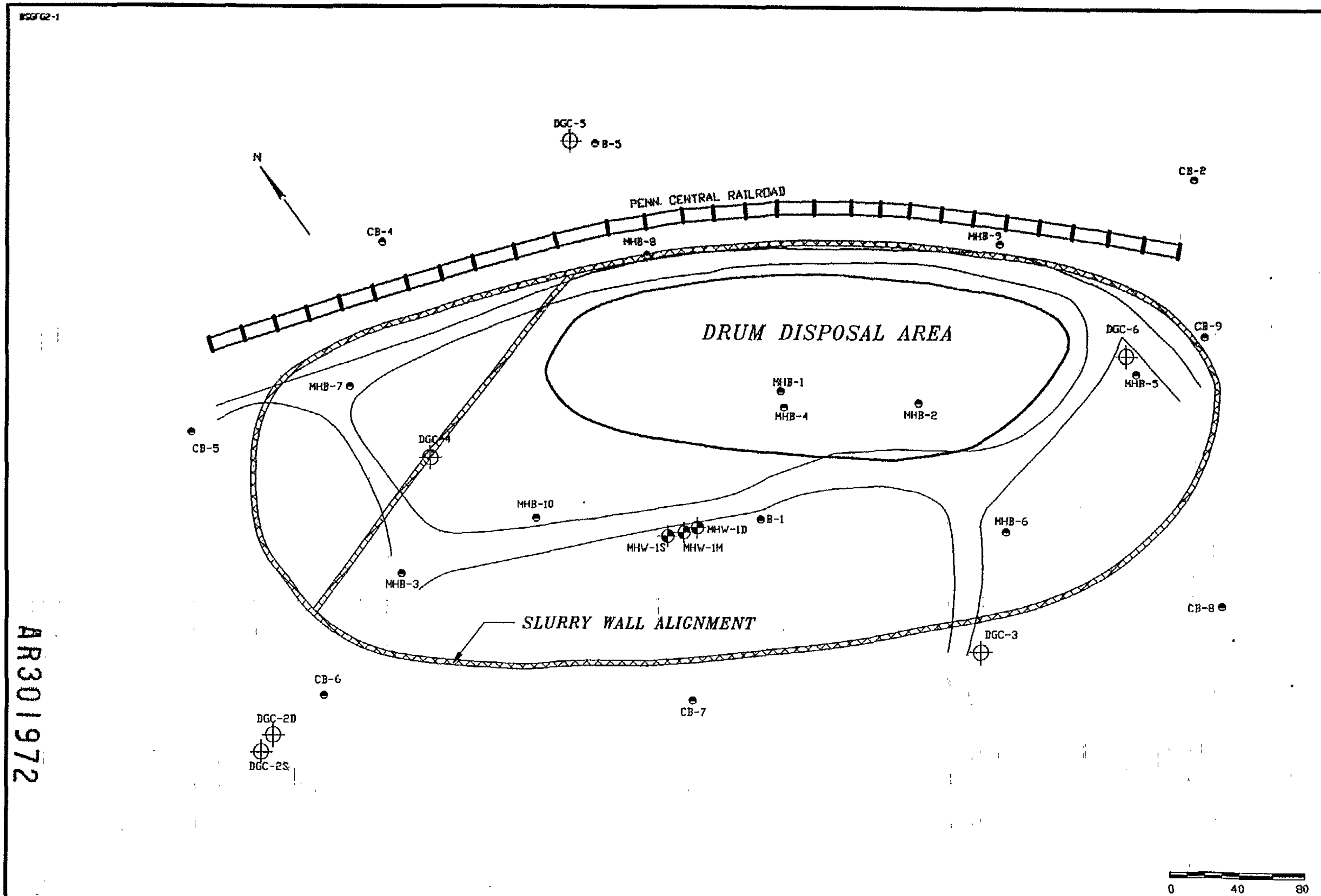
In addition, two chemical compatibility tests will be performed using on-site water to confirm actual performance. These tests will be conducted concurrently with the mix design studies (see Section 2.2.3). After the selection of the minimum and maximum range for bentonite content chemical compatibility permeability testing will be conducted using the minimum and maximum bentonite content. These will provide a range to determine the effect of the Site chemical on the slurry wall performance, if any. During McLaren/Hart's site investigation of 1991, three (3) monitoring wells, designated as MHW-1S, MHW-1M and MHW-1D were installed as a well cluster along the southwestern corner of the DDA. The two shallow wells (MW-1S and MW-1M) were installed to obtain information on water quality above Columbia and Potomac confining layer clays. These two wells will be used to obtain representative site-specific water samples to conduct the chemical compatibility tests.

A composite water sample (50% of MW-1S and 50% of MW-1M) will be used as the permeant to measure slurry wall performance. Permeability testing using ASTM Method D5084-90 will be utilized to access performance. A minimum of three pore volumes of water will be passed through the tested samples. In order to accomplish the testing within a reasonable time frame, high draulic gradients will be applied during the test. Furthermore, for each mix design, a baseline test using tap water under the identical hydraulic conditions will also be conducted. The baseline permeabilities will be compared to the permeabilities of each mix design to determine whether the contaminants in the groundwater affect permeability (i.e., slurry wall performance).



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- MCLAREN/HART SOIL BORING
- DUN[illegible] SCIENCE MONITORING WELL

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ENVIRONMENTAL ENGINEERING CORP.
LE[illegible]ER, PA

ALIGNMENT OF SLURRY WALL
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWA[illegible]

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2.2.3 Selection of Soil-Bentonite Mix Design

After it is confirmed that the Site specific contaminants are compatible with the soil-bentonite backfill mixture, a laboratory test will be conducted to determine the most cost-effective soil-bentonite mix design. The purpose of the mix design test is to identify the amount of bentonite required to form a soil/bentonite slurry with a permeability of less than 1×10^{-7} cm/sec. Test conditions (consolidation pressure and head differential) will be matched to typical conditions along the proposed slurry wall alignment.

After completion of the Drum Disposal Area Geotechnical Investigation, grain size and moisture content data (from all appropriate sources) will be compiled and analyzed to establish a "design soil". The design soil gradation will be a gradation such that 75% or more of the actual soil samples will be more fine-grained and have lower moisture content than the design soil. After the selection of the design soil gradation, sufficient quantity of a homogeneous batch of soil having the characteristics of the design soil will be prepared by proportionally mixing the soil collected from different boring locations. This design soil will be utilized in the mix design test. Various potential bentonite product vendors will be contacted to select one or more specific bentonite product(s) for use in the mix design test. As bentonite properties vary considerably, the mix design test program will be valid only for the specific bentonite product that is used in the test. Only those products used in the mix design test program, or products subsequently demonstrated to have equal properties will be permitted for slurry wall construction. A minimum and maximum range for bentonite content will be determined based on density, viscosity, and workability requirements. Within the minimum and maximum range, three (3) or five (5) specific bentonite contents will be selected for the purpose of testing. For baseline purposes, a sample of the design soil alone will also be included. Samples will be prepared by thorough mixing and screening of the selected soil through a No. 4 sieve to remove gravel-sized particles.

In the first step of the test, bentonite slurries anticipated for use in the trenching operations will be mixed by combining tap water and powered bentonite in appropriate ratios. The slurries will be allowed to hydrate for at least 24 hours after mixing. After hydration, the slurries will be combined with the design soil at its design water content. The quantity of slurry added to the

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design soil will be sufficient to produce a soil-bentonite mixture having a 4- to 6-inch slump. The soil-bentonite backfill mixture will be transferred to molds and consolidated under pressures not exceeding 10 psi until the samples are sufficiently stiff for mounting in the permeability testing equipment.

Permeability tests will be performed on each sample using ASTM Method D5084-90. Each test will be carried out over a period of 3 to 7 days and repeated as required. A load of 10 psi will be applied to the specimen in two or three equal increments to consolidate the sample. The specimen will be allowed to consolidate for 24 hours between applications of load increments. After the sample has been consolidated, the permeability of the sample will be obtained. Based on the testing results, the most cost-effective mix design will be determined and recommended for the design of the slurry wall.

2.3 DELINEATION OF THE INERT AREA

The objective of this study is to delineate the areal extent of the Inert Area. First, existing information (e.g., topographic map, historical aerial photographs, physical data, existing monitoring well and boring logs, etc.) will be reviewed to establish the approximate areal limits of the disposal area. Following the review of pertinent information, field reconnaissance will be conducted to augment the data review, and the approximate Inert Area boundaries will be identified on a map. After the field reconnaissance, all available information sources from the investigation will be compiled and analyzed to identify the questionable area(s), then test borings will be completed at 200 ft. intervals around the areas in question of the Inert Area to confirm the disposal area boundaries. Procedures for conducting the field reconnaissance and the confirmatory test boring investigation are outlined in Section 2.4.1 - Field Sampling Plan.

2.4 SAMPLING, ANALYSIS, AND MONITORING PLAN

The Sampling, Analysis and Monitoring Plan (SAMP) describes the sampling, testing and analysis methodology necessary to obtain additional site-specific geotechnical data and physical data as needed to perform the Slurry Wall and Inert Area Cap Design. This sampling and testing program does not attempt to confirm all existing data, but rather supplement data which is presently available. The SAMP is prepared as part of the RAP. The SAMP consists of a Field Sampling Plan (FSP), a Quality Assurance Project Plan (QAPjP), and a Health and Safety Plan, all of which are described in the following sections.

2.4.1 Field Sampling Plan

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2.4.1 Field Sampling Plan

The Field Sampling Plan (FSP) provides a detailed summary of the procedures to be followed during implementation of field investigations at the Delaware Sand & Gravel site located in New Castle, Delaware. Field activities will include a Site survey, a geotechnical soil boring program in the Drum Disposal Area, and field reconnaissance and a test boring program to delineate the extent of the Inert Area. The major components of the FSP common to each of the field tasks are listed below:

1. Maps depicting proposed sampling/surveying locations; and

2. A detailed description of all sampling, analysis, testing and monitoring to be performed including sampling methods, analytical and testing methods, and compatibility methodologies, frequency of sampling and sampling locations.

2.4.1.1 Site Survey

As the start of the Response Action pre-design activities, an updated Site and topographic survey will be prepared for the Drum Disposal and Inert Areas. All survey work will be conducted by a surveyor licensed and registered in the State of Delaware. The Site survey will include the locations of all existing structures (e.g., buildings, railroad tracks), monitoring wells and new test borings to be completed along the alignment of the slurry wall.

An existing bench mark shown in Figure 2-1 at the southeast end of the DDA will be tied into the Delaware State Plan Coordinate System and then used to establish the grid system as shown in Figure 2-1. New topographic base maps of the Drum Disposal and Inert Areas will be prepared at scale of 1" = 20 feet and 1" = 40 feet, respectively. Vertical control will be referenced to the National Geodetic Vertical Datum (NGVD), and horizontal control will be referenced to the Delaware State Plane Coordinate system, obtained from a permanent bench mark at the Site.

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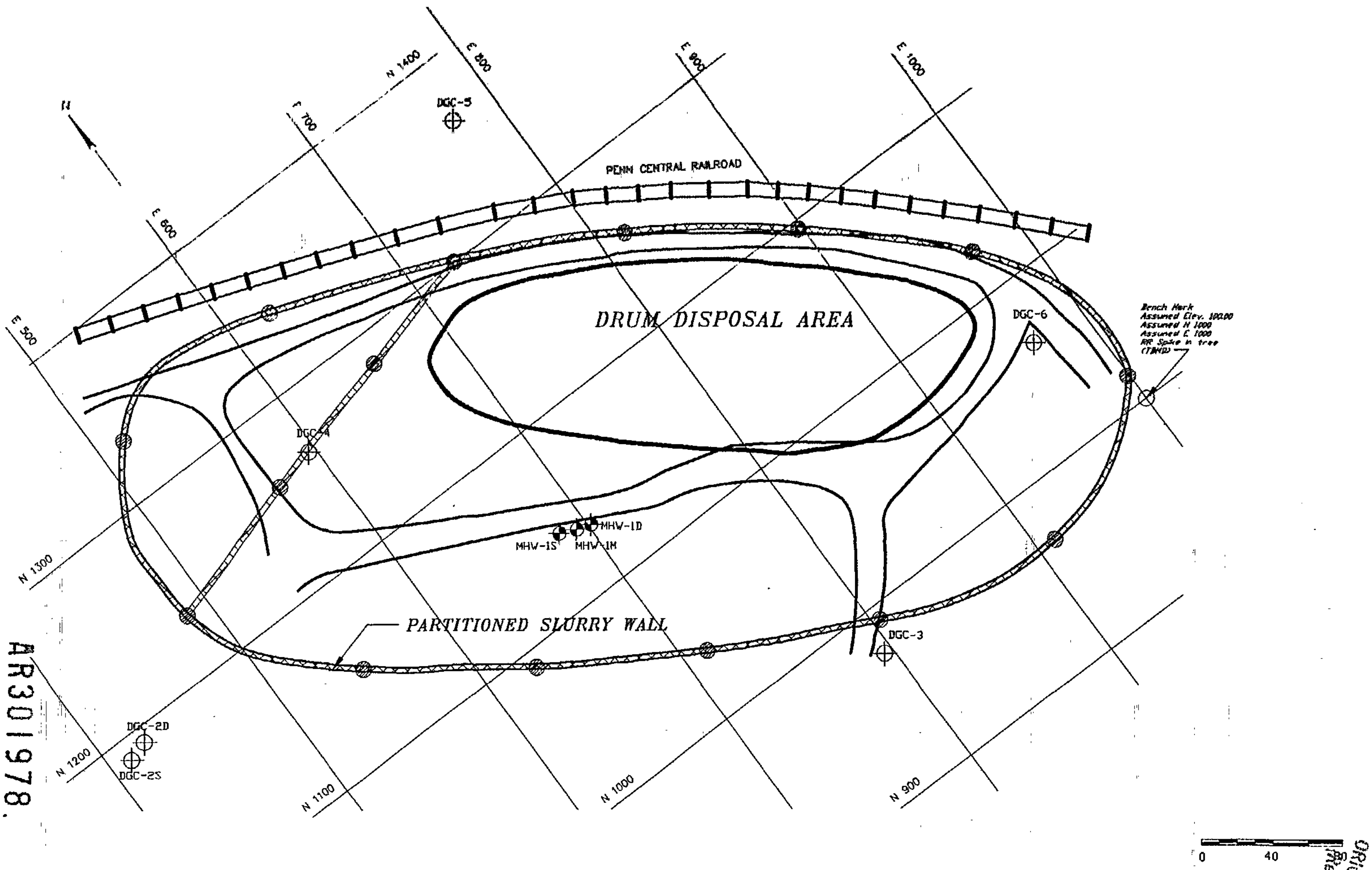
2.4.1.2 Drum Disposal Area Geotechnical Investigation

The Drum Disposal Area soil boring program will be used to more thoroughly characterize site geology and to obtain soil samples for geotechnical analyses. A primary objective of the field investigation will be to determine the depth to the Upper Potomac Confining Layer along the alignment of the proposed slurry wall.

Figure 2-2 shows the alignment of the Slurry Wall and the potential test boring locations. Test borings will be completed at approximate 100 foot centers along the alignment. Additional test borings will be added if field conditions show inconsistencies between initial borings at 100 foot spacing. It is currently estimated that a total of 15 test borings will be performed along the Slurry Wall alignment. Actual test boring locations will be determined, surveyed, and tied into the Delaware State Plan Coordinate system during the initial inspection and site survey. All test boring locations will be cleared as needed using heavy equipment to provide drill rig access, surveyed and then marked with wooden stakes or pin flags prior to the initiation of drilling activities. The field team conducting the initial inspection and site survey of the test boring locations will have the following equipment:

- 4-foot wooden stakes;
- mallet;
- machete;
- orange, non-toxic spray paint;
- orange flagging;
- 200 foot tape;
- compass;
- portable two-way radios; and
- site maps & aerial photographs.

All drilling activities will be completed using 4 1/4 inch I.D. hollow stem augers (HSA). Split-spoon samples will be collected continuously at 2-foot intervals until three (3) feet of clay is encountered or the bottom of the Potomac clay layer is encountered, whichever is shallower. The on-site geologist will refer to the geologic cross-sections provided in Appendix A prior to



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SLURRY WALL TEST BORING LOCATION
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

DATE: 9-21-92
APP'D: K.P.

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advancing test borings. Soil cuttings will be field screened for organic vapors using an HNu photoionization meter. Soil cuttings will be containerized in 55-gallon drums if HNu readings are above 100 ppm and/or visual observations indicate evidence of organic contamination. If soil cuttings are clean, soils will be spread on the ground surface adjacent to the boring.

Field boring logs will include the following information:

- sample location and depth;
- color, grain-size, lithology and sorting;
- degree of saturation; and
- unusual features (organic odors, staining).

Soil sample descriptions will be based on the Unified Soil Classification System (USCS) using the parameters outlined in Table 2-1.

Large diameter (3-inch) split-spoons will be used for collection of soil for geotechnical laboratory tests. Split-spoons will be advanced using a standard 140-pound hammer with a free fall of 30-inches. The number of blows required to advance the 3-inch spoon will be recorded in 6 inch intervals on the log. Upon completion of field work, the number of blows required to drive the spoon the middle twelve inches of its 24 inch length will be corrected using the Burmister relationship listed below to account for use of the 3-inch spoon in place of the standard 2-inch spoon. This value will be recorded as the standard penetration resistance value (N-value) for use in geotechnical characterization of site soils.

Blow Count Relationship

$B = B'[(D_o^2 - D_i^2)/2.22]$

where:

B = Corrected Blow Count

B' = Measured Blow Count in Field

D_o = Spoon Outside Diameter

D_i = Spoon Inside Diameter

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TABLE 2-1
CLASSIFICATION OF SOILS

I. Criteria for Assigning Soil Group Names ASTM D-2487-90			Group Symbol	Group Name
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels - More than 50% of coarse fraction retained on No. 4 sieve Coarse, 3/4" to 3" Fine, No. 4 to 3/4"	Clean Gravels Less than 5% fines	GW	Well graded gravel
			GP	Poorly graded gravel
		Gravels with fines more than 12% fines	GM	Silty gravel
			GC	Clayey gravel
	Sands - 50% or more of coarse fraction passes No. 4 sieve Coarse, No. 10 to No. 4; Medium, No. 40 to No. 10; Fine, No. 200 to No. 40	Clean Sands Less than 5% fines	SW	Well graded sand
			SP	Poorly graded sand
		Sands with fines more than 12% fines	SM	Silty sand
			SC	Clayey sand
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays - Liquid Limit less than 50 Low to medium plasticity	Inorganic	CL	Lean clay
			ML	Silt
		Organic		Organic clay
			OL	Organic silt
	Silts and Clays - Liquid Limit 50 or more Medium to high plasticity	Inorganic	CH	Fat clay
			MH	Elastic silt
		Organic		Organic clay
			OH	Organic silt
Highly Organic Soils	Primarily fibrous organic matter, dark in color, and organic odor		PT	Peat

II. Definition of Minor Component Proportions

Minor Component	Approximate Percentage of Fraction by Weight
Adjective Form	
Gravelly, Sandy	30% or more coarse grained
Silty, Clayey	12% or more fine grained
With	
Sand, Gravel	15% or more coarse grained
Silt, Clay	5% to 12% fine grained
Trace	
Sand, Gravel	Less than 15% coarse grained
Silt, Clay	Less than 5% fine grained
Contains	Presence only

III. List of Additional Identification Items

Symbols
Unified Soil Classification Symbols are shown above as group symbols. Use A Line Chart for laboratory identification. Dual symbols are used for borderline classifications.

Fill -	Man made deposit containing soil, rock and often foreign matter.
Probable Fill -	Soils which contain no visually detected foreign matter but are suspect with regard to origin.
Lens -	0 to 1/2 inch seam of minor soil component.
Layer -	1/2 to 12 inch seam of minor soil component.
Pocket -	Small erratic deposit of minor soil component.
Color Shades -	Major color groups - Brown, Tan, Yellow, Green, Red, White, Gray, and Black Light to dark to indicate substantial difference in color
Moisture Conditions -	Wet, moist, or dry to indicate visual appearance of sample.

Cobbles and Boulders
Cobbles are considered rounded pieces of rock which range from 3 to 12 inches, while boulders are larger than 12 inches in size.

Disintegrated Rock
Residual material with a standard penetration resistance (SPT) of more than 60 blows per foot (N-value), and less than refusal. Refusal is defined as a SPT of 100 blows for 2" or less penetration.

Rock Fragments
Angular pieces of rock, distinguished from transported gravel, which have separated from original vein or strata and are present in a soil matrix.

Cemented Sand
Usually localized rock-like deposits within a soil stratum composed of sand grains cemented by calcium carbonate or other materials.

Mica
A soft plate of silica mineral found in many rocks, and in residual or transported soil derived therefrom.

Organic Materials (excluding peat):
Topsoil - Surface soils that support plant life and which contain considerable amounts of organic matter;
Organic Matter - Soil containing organic colloids throughout its structure;
Lignite - Hard, brittle decomposed organic matter with low fixed carbon content (a low grade of coal).

Samples of each split-spoon for geotechnical laboratory tests will be transferred into clean, wide-mouth drillers jars and labeled with the following information:

- Project name;
- Boring location;
- Date and time collected;
- Sample depth; and
- Geologist's initials.

Grain-size analyses will be performed on an as-required basis to definitively characterize all soils. At least two (2) split-spoon samples from each test boring will be selected for laboratory grain-size analysis by the on-site geologist and/or geotechnical engineer. Grain-size analyses will be performed in accordance with ASTM Method 422. Each grain-size analyses will be accompanied by the Moisture Content Test per ASTM D2216 and Atterberg Limit Test per ASTM D4318. The on-site geologist and/or geotechnical engineer should also combine similar samples from a single stratum encountered in a boring to establish stratum properties. A field head space analysis for organic vapors will be performed on each sample using an HNu Photoionization meter. If elevated levels of organic vapors are detected in a sample, this information will be supplied to the geotechnical laboratory to ensure that adequate precautions are taken before handling the sample material. In addition, a 24-hour groundwater level will be established in each boring, if possible, prior to grouting the boring. All borings will be grouted with cement.

2.4.1.3 Delineation of the Inert Area

After existing documents on the Inert Area have been reviewed (e.g., topographic maps, historical areal photographs, physical data, existing monitoring well and boring logs), field reconnaissance will be conducted to map out the approximate disposal area boundaries. The field reconnaissance team will mark the boundary of the disposal area. Test borings will be conducted about the areas in question. The field team will identify locations for confirmatory test borings at 200 ft. intervals and take note of any areas where drill rig access may be problematic and/or clearing may be needed using heavy equipment. The Inert Area boundary will be marked using stakes with high-visibility flagging and/or fluorescent, non-toxic spray paint.

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Test boring locations will be marked using 4-foot wooden stakes and flagging at 200 foot intervals around the perimeter of the Inert Area. The field equipment needed for the Inert Area field reconnaissance will consist of the same items listed in Section 2.4.1.2 for the Drum Disposal Area investigation. Test borings will be completed using 4-1/4 inch I.D. hollow stem augers. Test borings will be advanced until a significant layer (1 to 2 ft.) of waste material is encountered or to a depth of 25 feet, whichever is shallower. Based on test boring logs previously completed at the Site, the waste material can be expected to consist of typical municipal trashes. In the event that a test boring encounters waste material, the drilling location will be moved out from the approximate perimeter of the Inert Area by approximately 25 feet and then re-drilled until no significant layer of waste material is observed. Test boring logs will be documented in the same manner as described in Section 2.4.1.2 for the Drum Disposal Area test borings.

2.4.2 Quality Assurance Project Plan

The Site work to be performed under the design investigations will result in the collection of site-specific geotechnical samples, as well as other important Site data as described in Section 2.4.1. In order to ensure the accuracy, precision and completeness of this data, a Quality Assurance Project Plan (QAPjP) has been prepared. The contractor, in conjunction with the analytical laboratories to be used, will be responsible for implementation of the QAPjP.

Due to the volume of information contained in the QAPjP, it has been prepared as a separate document (Appendix B). This will facilitate field usage and distribution to the analytical laboratories. The QAPjP is hereby incorporated into, and made a part of this RAP by reference.

2.4.3 Health and Safety Plan

The Site work to be performed under the design investigations might involve a wide range of hazardous substances. These substances and conditions might give rise to a number of risks and hazards to the health and safety of on-site workers participating in the work. In order to ensure the health and safety of the Site workers, a Health and Safety Plan (HASP) for the design investigations has been prepared. The contractor will be responsible for implementation of the HASP.

Due to the volume of information contained in the HASP, it has been prepared as a separate document (Appendix C). This also has been done to facilitate field usage and distribution to interested parties. The HASP is hereby incorporated into and made a part of this RAP by reference.

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3.0 SLURRY WALL AND INERT AREA CAP DESIGN

The Slurry Wall and Inert Area Cap design will include a number of activities in addition to the design investigations described in Section 2.0. These design activities will include engineering analysis and design as well as the preparation of various design reports, construction plans, and permit or permit equivalent applications. The design works will follow parallel tracks as shown in Figure 1-2 relative to the design development for the Slurry Wall and Inert Area Cap.

The plans for performing the individual design tasks as described in this section will be in conformance with the specific requirements of the Consent Order, the Superfund Remedial Design and Remedial Action Guidance document[1], and other relevant U.S.EPA guidance. To allow for Committee and U.S.EPA review, comment and approval, design reports will be submitted at the following major stages of development:

- preliminary design (Preliminary Design Report) (30% complete)
- pre-final/final design (Pre-Final/Final Design Report 90%-100% complete)

This sequence will be followed so that the plans and specifications that have been completed can be compiled at important points for U.S.EPA review, comment and approval. A design analysis will be prepared for each design phase, and incorporated into each design report.

The following sections present detailed descriptions for the work to be conducted during the design. All sections apply to both Slurry Wall and Inert Area Cap design, except Section 3.2.8 applies to Slurry Wall design only.

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[1]OSWER Directive No. 9355.O-4A, June 1986.

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3.1 DESIGN REPORTS

3.1.1 Preliminary Design Report

The Preliminary Design Report will include a description and analysis of various design options for the Slurry Wall and Inert Area Cap. The results of the design investigation will be summarized in this report. Based on the information obtained from the design investigation, the Preliminary Design Report will recommend a preferred conceptual design. The design analysis will provide the rationale for recommending a preferred conceptual design, including supporting calculations and documentation of how such design will meet the requirements of the Consent Order. The design report shall include the following items:

(1) A discussion of the design criteria and objectives, with emphasis on the capacity and the ability to successfully meet design objectives. The design criteria and objectives should address permeability of both the Upper Potomac Confining Layer and the soil bentonite slurry wall. The preliminary design will include a value engineering analysis. The purpose of value engineering is to determine the most cost-effective means for achieving the design objective. During value engineering, issues such as the final soil-bentonite mix design for the Slurry Wall and the final configuration of the Inert Area cap will be considered. Analytical modeling will also be conducted to evaluate worst-case and probable-case scenarios for groundwater movement through the slurry wall and confining layer. The preliminary design report will also include a detailed evaluation of the cap component alternatives evaluation, gas venting system, and potential availability of borrow material.

(2) Table of contents for design specifications, including a listing of specification items from the Construction Specifications Institute master format expected to be included in the construction specifications or the actual specifications.

(3) Site security measures.

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(4) Site safety and emergency measures.

(5) Preliminary plan view(s) for Site preparation and layout.

(6) Preliminary plans and profiles illustrating areas to be excavated.

(7) Plans for collection and conveyance of excavated materials.

(8) Preliminary construction material recommendations.

(9) Preliminary construction drawings of standard size, will include proposed work, facilities, equipment, improvements, details and all other construction and installation items as well as drawings representing an accurate identification of existing Site conditions. More specifically, these drawings will include:

- Title sheet bearing at least the title of the project, a key map, the name of the designer, date prepared, sheet index, U.S.EPA project identification, etc.

- All property data including owners of record for all properties within 200 feet of the Site.

- The distance and bearing of all property lines which identify and define the project Site.

- All easements, rights-of-way and reservations.

- All buildings, structures, facilities, controls, equipment and features, existing and proposed.

- A topographic survey, including existing and proposed contours and spot elevations, based on U.S. Geological Service datum.

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- All utilities, existing and proposed.

- Location and identification of all significant natural features including, but not limited to, wooded areas, water courses, wetlands, flood hazard areas and depressions.

- Flood hazard data and delineation, if applicable.

- North arrow, scale, sheet numbers and the person responsible for preparing each sheet.

- Decontamination areas, staging areas, and stockpiling areas.

- Stormwater drainage/diversion ditch system and stormwater detention system details, as needed.

- Miscellaneous detail sheets.

- Definitions of all symbols and abbreviations.

3.1.2 Pre-Final/Final Design Report

The Pre-Final/Final Design Report will include the plans and specifications which have been completed, together with a design analysis. The design analysis will provide the rationale for the plans and specifications, including supporting calculations and documentation of how these plans and specifications will meet the requirements of the Consent Order. The design report will also include the following items:

(1) Final analysis of the design criteria and objectives, with emphasis on the capacity and the ability to successfully meet design objectives.

(2) Completed Design Specifications.

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(3) Site security measures.

(4) Site safety and emergency measures.

(5) Plan view(s) for Site preparation and layout.

(6) Plans and profiles illustrating areas to be excavated.

(7) Plans for collection and conveyance of excavated materials.

(8) Construction Drawings.

(9) Construction material recommendations.

(10) A report of efforts made to secure access and obtain other approvals and of the results of those efforts. Legal descriptions of property or easements to be acquired shall be provided including property owners, Site operators, addresses and lot and block numbers, and grantors and grantees of easements.

The Pre-Final/Final Design Report will also include: Construction drawings, of standard size, of proposed work, facilities, equipment, improvements, details and all other construction and installation items as well as drawings representing an accurate identification of existing Site conditions. Increased levels of detail will be incorporated with pre-final/final design reports corresponding to the percent completion of the engineering design and specification of materials.

3.2 CONSTRUCTION WORK PLAN

Following U.S.EPA approval of the Pre-Final/Final Design Report, a Construction Work Plan will be developed for the construction phase of work. The following subsections present detailed descriptions for the items to be included in the construction work plan, as outlined in the SOW.

3.2.1 Sampling, Analysis and Monitoring Plan for Construction

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A SAMP will be prepared for the sampling, analysis, testing and monitoring activities that will be conducted during the construction phase work. The SAMP for the construction phase will discuss procedures for sample collection, locations of sampling points and the rationale for their selection, analytical parameters, frequency of sampling, and quality assurance/quality control procedures.

The construction-phase SAMP will prescribe field sampling methods selected from the appropriate U.S.EPA Field Sampling Procedures Manual. Sampling procedures which differ from those specified in the U.S.EPA manual will be fully documented and referenced to established methods or procedures.

The construction-phase SAMP will describe the testing of construction materials prior to use, and testing of constructed components to assure that they meet design specifications. Additionally, the SAMP will describe detailed inspection, sampling and analysis procedures for testing of excavated waste materials.

The SAMP for construction-phase environmental monitoring activities will specify that sample analyses be performed according to U.S.EPA Contract Laboratory Program (CLP)[2] protocol's (where appropriate and applicable), or with methods described in Test Methods for Evaluation Solid Wastes.[3] The SAMP will also specify that data deliverables for analyses performed according to CLP protocols be submitted according to CLP criteria and format. For analyses performed according to non-CLP methodologies, the SAMP for construction activities will require that data deliverables be in a format similar to CLP format, if appropriate. The SAMP will include an example of the non-CLP deliverable format.

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[2]CLP methods are those contained in the "USEPA Contract Laboratory Program Statement of Work, Inorganic Analysis" (revised 12/87), "USEPA Contract Laboratory Program Statement of Work for Organic Analysis," (Feb. 88), and "USEPA Contract Laboratory Program Statement of Work for Dioxin Analysis," (Sept. 86).

[3]SW-846, 3rd Edition, November 1986.

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A major element of the construction-phase SAMP will be a Quality Assurance Project Plan (QAPjP) to address quality assurance requirements and standards relating to construction operations. These requirements and standards may include (but are not limited to) construction of the staging area and access roads. Quality assurance factors that will be addressed include:

- inspection of the work;
- daily construction logs and reports;
- preparation of as-built drawings;
- testing of the work to establish whether the design specifications are attained; and
- plans for photographic documentation of the construction (see Section 3.2.7).

In addition to the construction quality assurance, the QAPjP will cover all environmental monitoring performed during the construction phase. These monitoring aspects of the QAPjP will be in accordance with the U.S.EPA Quality Assurance Manual. At a minimum, the QAPjP for the construction phase will include:

- title page and table of contents;
- project description;
- project organization and responsibility;
- quality assurance objectives;
- sample custody procedures;
- calibration procedure and frequency;
- analytical procedures;
- procedures for data reduction, validation and reporting;
- internal quality control checks;
- performance and system audits;
- preventive maintenance;
- specific routine procedures for assessing data precision, accuracy and completeness;
- corrective action;
- QA reports to management.

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The SAMP will further specify that sample custody procedures be in conformance with U.S.EPA chain-of-custody protocols as described in National Enforcement Investigations Center Policies and Procedures Manual, (revised May 1986).

3.2.2 Health and Safety Requirements for Construction

As part of the Construction Work Plan, specific HASP requirements governing all on-site construction activities will be prepared. These requirements will be in the form of detailed specifications for preparation and implementation of the HASP, rather than as a formal HASP.

This approach is necessary because the construction-phase HASP will be equipment/personnel/contractor and technology specific, and this high degree of specificity cannot be taken into account during the design phase. It is likely that prospective construction contractors will submit draft versions of the construction-phase HASP as part of their bid submittals. Final versions of the construction phase HASP will be prepared after contract award and prior to initiating construction activities.

Preparation of the construction-phase HASP specifications will be initiated through a review of the available project information including HASPs from previous phases of work at the Site (RI HASP and RAP HASP). After this review, detailed specifications will be prepared. The construction contractor will then prepare a final HASP for the construction period. The HASP specifications will include the minimum health, safety and emergency response requirements for which the construction contractor will be made responsible, and which must be included in the final HASP developed by the construction contractor.

The draft HASP specifications will be prepared with consideration of applicable Federal and State regulations and guidance. Reference documents that may be reviewed (or cited as references in the specifications) include:

- CERCLA sections 104(f) and 111(c)(6);
- U.S.EPA Order 1440.1 - Respiratory Protection;
- U.S.EPA Health and Safety Audit Guidelines - SARA Title 1 - Section 126

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- U.S.EPA Occupational Health and Safety Manual;
- U.S.EPA Interim Standard Operating Safety Guide;
- OSHA Standards for General Industry (29 CFR 1910);
- NIOSH Manual of Analytical Methods;
- ANSI 288.2-1980: Practices for Respiratory Protection;
- Latest edition of ACGIH TLVs; and
- ACGIH - Air Sampling Instruments for Evaluation of Atmospheric Contaminants.

The construction-phase HASP prepared by the construction contractor will include, at a minimum, the following items:

- plans showing the location and layout of temporary facilities (i.e., decontamination pads, trailers, etc.) to be constructed;
- description of known hazards and an evaluation of the risks associated with the Site and the potential health impacts related to the construction activities;
- identification of personnel responsible for site safety, response operations and communication;
- description of the levels of protection and the respective equipment to be utilized;
- delineation of work zones, procedures for movement between zones and a map showing the work zones;
- description of decontamination procedures;
- incident emergency response and personnel evacuation procedures;
- description of the medical surveillance program;
- description of site safety monitoring procedures;

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- routine and special personnel training programs; and

- air monitoring program to determine the concentrations of airborne hazardous substances to which on-site workers and persons in the vicinity of the site may be exposed.

The construction HASP will incorporate all the provisions as found within 29 CFR 1910.120, which by reference, include all provisions contained within 29 CFR 1910, General Industry Standards, and 29 CFR 1926, Construction Standards. Safety guidelines for heavy equipment operation should be a major consideration for this HASP.

The draft construction-phase HASP specifications will be submitted to U.S.EPA as part of the Construction Work Plan.

3.2.3 Construction Operations Plans

The Respondents will prepare a Construction Operations Plan which will address the methods by which construction activities will be executed. This discussion will include the timing of, and manner in which construction activities will be sequenced. The Construction Operations Plan will be incorporated into the final bidding documents as part of the technical specifications to which the successful contractor will be bound.

Preparation of the Construction Operations Plan will include a number of separate components. The first component will be detailed requirements for preparation of the Site including:

- provision of utility services;
- storage of construction equipment;
- construction of decontamination facilities;
- set-up of construction and office trailers; and
- other site work.

The sequence for executing these preparatory activities and the rationale for that sequence will also be defined in the Construction Operations Plan.

The second component of the Construction Operations Plan will be sequencing and coordination of construction activities.

The Construction Operations Plan will also include a discussion of the Site inspections and maintenance activities that will be performed during the construction phase. This construction-phase Site Maintenance Plan will detail the frequency of Site inspections, format for documenting the inspections, and procedures for instituting and documenting corrective action for deficient items, if any.

The Construction Operations Plan will detail the plans and procedures for coordinating with local authorities regarding contingency planning and traffic flow. Coordination with local authorities regarding contingency plans will be necessary due to the proximity of the Site and the access roads to nearby housing. Local authorities could conceivably be called upon to institute evacuation or public notifications, and to provide emergency services (fire, ambulance, police, etc.). The Construction Operations Plan will describe the responsibilities of the various authorities, points-of-contact, criteria for determining when local resources will be contacted, and procedures for transferring responsibility for Site control.

The Construction Operation Plan will also detail the plans and procedures for dust control and erosion control.

3.2.4 Construction Schedule

The Respondents will prepare a detailed schedule for the construction work. This schedule will be in the form of a task Gantt Chart similar to that shown in Figure 4-2. The schedule for construction will be prepared so as to indicate tasks that are on the critical path (wherein a change in task duration will affect the final project completion date). As with the draft schedule shown in Section 4.2, revisions to the construction schedule will include tasks for U.S.EPA review and approval of key submittals.

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The final schedule for construction will be prepared after the Construction Operations Plan has been completed. This sequence will be followed because the Construction Operations Plan will include details regarding sequencing of the site activities, that will define durations of those activities. The construction schedule will be submitted to U.S.EPA and the State as part of the Construction Work Plan.

3.2.5 Operation and Maintenance Plan

As a part of the Construction Work Plan, an Operation and Maintenance Plan for the O&M phase of the work will be prepared. The O&M phase will start when the construction work is complete. O&M activities during the construction phase will be addressed in the Construction Operations Plan.

At a minimum, the O&M Plan will include the following major components:

- a Sampling, Analysis and Monitoring Plan (SAMP);
- a Health and Safety Plan (HASP); and
- an O&M schedule.

The O&M Plan will also address the following items:

- description of equipment;
- description of routine O&M tasks;
- description of potential operating problems;
- description of alternate O&M in the event of system failure;
- schedule of equipment replacement; and
- effectiveness Monitoring Plan.

The O&M Plan will be prepared after the Construction Operations Plan has been completed. This sequence will be followed because the activities described in the Construction Operations Plan may have special or unique post-construction operation or maintenance requirements. Details regarding each of the major components of the O&M Plan are discussed below.

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3.2.5.1 Sampling, Analysis and Monitoring Plan

The first major component of the O&M Plan will be a SAMP covering relevant O&M activities. The SAMP for the O&M phase will discuss procedures for sample collection, locations of sampling points and the rationale for their selection, analytical parameters, frequency of sampling and quality assurance/quality control procedures.

The SAMP will prescribe field sampling methods selected from the Procedures Manual. Sampling procedures which differ from those specified in the U.S.EPA manual will be fully documented and referenced to established methods or procedures.

The SAMP for O&M activities will specify that sample analyses be performed according to U.S.EPA Contract Laboratory Program (CLP)[4] protocols (where appropriate and applicable), or with methods described in Test Methods for Evaluating Solid Wastes.[5] The SAMP will also specify that data deliverables for analyses performed according to CLP protocols be submitted according to CLP criteria and format, if appropriate. For analyses performed according to non-CLP methodologies, the SAMP for O&M activities will require that data deliverables be in a format similar to CLP format. The SAMP for O&M activities will include an example of the non-CLP deliverable format.

Other elements of the SAMP for O&M activities will include:

- maps or figures illustrating proposed sampling locations; and
- a Quality Assurance Project Plan for O&M Activities (QAPjP for O&M) completed in accordance with the requirements of the U.S.EPA CERCLA Quality Assurance Manual.

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[4]CLP methods are those methods contained in "USEPA Contract Laboratory Program Statement of Work, Inorganic Analysis," (revised 12/87), "USEPA Contract Laboratory Program Statement of Work for Organic Analysis," (Feb. 88), and "USEPA Contract Laboratory Program Statement of Work for Dioxin Analysis," (Sept. 86).

[5]SW-846, 3rd Edition, November 1986.

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The SAMP for O&M activities will include all of the elements described in Section 3.2.1.

3.2.5.2 Health and Safety Plan

A HASP for O&M activities will be prepared to ensure the safety and protection of health for workers participating in the O&M activities. The HASP for O&M activities will include all of the elements described in Section 3.2.2.

3.2.5.3 Operation and Maintenance Schedule

The O&M Plan will include a detailed schedule for all O&M activities associated with the O&M phase of work. The O&M schedule will be prepared as described in Section 3.2.6 and 4.3, and will be included in the O&M Plan.

3.2.6 Schedule for O&M Activities

The Respondents will also prepare a detailed schedule for the operation and maintenance activities. This O&M schedule will be in the form of a task Gantt Chart similar to that shown in Figure 4-3, including all of the post-design phase operation and maintenance activities that will be performed.

The final O&M schedule will be prepared after the Construction Operations Plan and Operation & Maintenance Plan have been completed. This sequence will be followed because these plans will define the O&M tasks to be performed, as well as the frequency and duration of those tasks. The O&M schedule will be submitted to U.S.EPA and the State as part of the Construction Work Plan.

3.2.7 Plans for Photographic Documentation of the Construction

As part of the Construction QAPjP, the Respondents will develop written plans and procedures for photographic documentation of the construction work. These plans will be implemented by the contractor selected for oversight and inspection of the construction activities.

The plans for photographic documentation will be based upon the sequencing of construction activities as discussed in the Construction Operations Plan (see Section 3.2.3). A schedule of planned documentation including number of still shots, number of prints, sizes of prints and other relevant information will be prepared for each phase of the construction work. These plans will also describe the procedures to be followed for labelling construction photos with (but not limited to) the following information:

- date and time of exposure;
- name of photographer; and
- description of photograph.

The plans for photographic documentation may also include the use of video recording. If so, the Respondents will prepare a schedule of events or activities that will be videotaped and the desired footage of each event or activity. The documentation plans will specify procedures for cataloging, labelling, duplication and storage of videotapes.

The Respondents will furnish copies of the photographic documentation to U.S.EPA. Photographs will be provided so as to record the progress of construction including, but not limited to, the important features of the Site prior to the commencement of the work, construction activities for the various tasks, and the appearance of the Site after the construction has been completed. These photographs will be developed expeditiously, and will be submitted to U.S.EPA and DNREC as part of the monthly progress report for the month in which the photographs are developed.

3.2.8 Plan to Handle Contaminated Soils

As a part of the slurry wall construction, site soil will be excavated along slurry wall alignment. As a part of the Construction Work Plan, a detailed plan will be developed for handling contaminated soils during the slurry wall construction around the Drum Disposal Area.

Soil samples for field screening purposes will be collected at regular intervals during excavation activities. An HNu Photoionization meter will be used to conduct volatile organic head space

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analyses. Based on the field screening and laboratory analysis data obtained during previous investigations, excavated materials which register above 100 ppm on the HNu will be segregated and stockpiled on-site in a designated area. Clean soil will be used to make slurry for the wall construction, or will be used as backfilling materials. The criteria of 100 ppm was established based on an evaluation of field HNu readings and chemical analytical results obtained during McLaren/Hart's investigation conducted between June and August 1991.

Contaminated soils will be stockpiled on sixty (60) mil High Density Polyethylene (HDPE) sheet. The stockpiled soils will be covered with six (6) mil polyethylene film to minimize erosion from the stockpile. The sides of the piles will be dressed to an outline of approximately one vertical to two horizontal. The top of the pile will be graded to ensure drainage without bumps or hollows which would pond water. These soils will be remediated along with other DDA soils.

3.2.9 Site Security Plan

As a part of the Construction Work Plan, a Site Security Plan will be developed to address routine security measures of the Site during the construction and post-construction periods.

The principal security activities during the construction and post-construction phases will be:

- periodic inspection of (and necessary repairs to) the Site security systems; and
- periodic inspection of the Site monitoring system.

3.2.10 Fire Protection and Prevention Plan

A Fire Protection and Prevention Plan will be prepared during the development of the Construction Work Plan. This plan will be prepared to control and prevent fires/explosions which may occur during the construction and post-construction periods. This plan will be also prepared to provide response procedures to be followed by Site personnel during a fire/explosion emergency.

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3.3 PERMIT OR PERMIT EQUIVALENT APPLICATIONS

Another design activity that will be performed by the Respondents is the preparation of permit or permit equivalent applications for work that will be performed at the Site, if required, since the response action is a CERCLA action.

The Respondents will be responsible for identifying all permits or permit equivalents that may be required. This will be accomplished by evaluating ARARs and conducting a meeting with the various Federal, State and local regulatory authorities which have jurisdiction over the Site or the activities that will be performed. Separate meetings will be held with appropriate branches of the U.S.EPA, DNREC and other agencies. Each meeting will cover:

- description of the work or activities to be conducted;
- assessment of applicability of permitting requirements;
- review of necessary forms and supporting information requirements;
- review of submittal requirements (number of copies, fees, addresses); and
- discussion of agency review procedures.

After the initial agency meetings, the Respondents will prepare a summary listing of all permit or permit equivalent applications that may be required. This summary will be in the form of a letter report with minutes of each meeting attached as supporting information.

The Respondents will prepare the initial application submittals including all required forms, sketches, drawings, narratives, calculations and other supporting information. Copies of the initial submittals will be provided to U.S.EPA and DNREC in accordance with the requirements of the Consent Order.

After the initial submittals, the Respondents will address regulatory agency comments. Additionally, the Respondents will address comments identified during U.S.EPA technical reviews.

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4.0 PROJECT SCHEDULES

4.1 SLURRY WALL AND INERT AREA CAP DESIGN

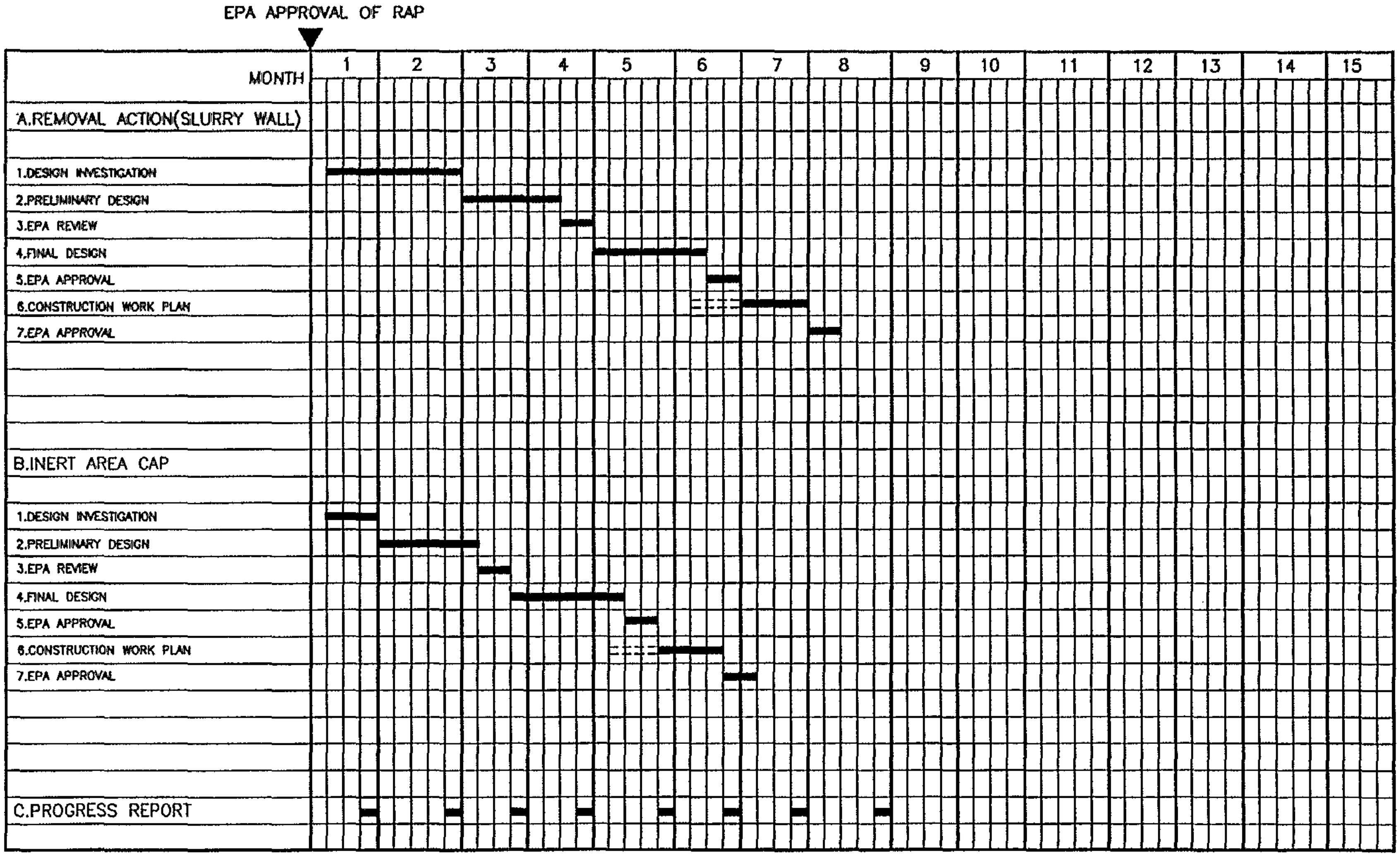
Figure 4-1 describes the schedule for design investigation and design activities for the Response Action. Completion of the design work will be accomplished within eight months.

4.2 DRAFT SCHEDULE FOR SLURRY WALL CONSTRUCTION

A draft preliminary schedule for the construction activities of the Slurry Wall is shown in Figure 4-2. This schedule has also been compiled on a total months basis. The draft schedule for construction includes the procurement and contractor selection phases. The final schedule for construction will be submitted to U.S.EPA as part of the Construction Work Plan reports (see Section 3.2.4).

4.3 DRAFT SCHEDULE FOR SLURRY WALL O&M ACTIVITIES

A draft preliminary schedule for the operation and maintenance activities for the Slurry Wall is shown in Figure 4-3. This schedule encompasses the operation and maintenance activities that will be conducted after completion of construction.



McLaren Hart

McLAREN/HART
ENVIRONMENTAL ENGINEERING CORP.
LE[illegible]R, PA

SLURRY WALL AND INERT AREA CAP DESIGN SCHEDULE
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

DATE: 7-30-92
APP'D: J.W.
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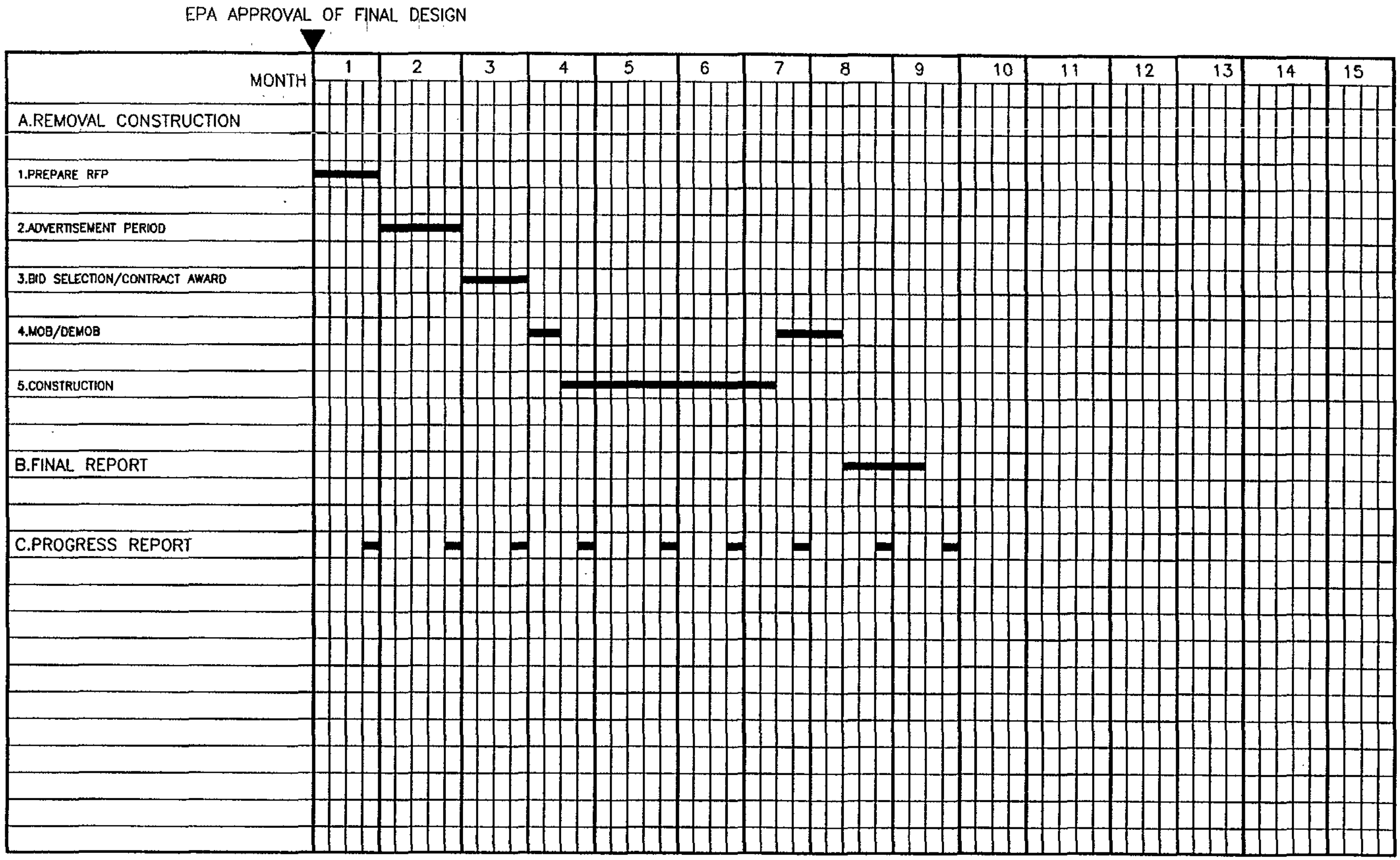

McLAREN/HART
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LESTER, PA

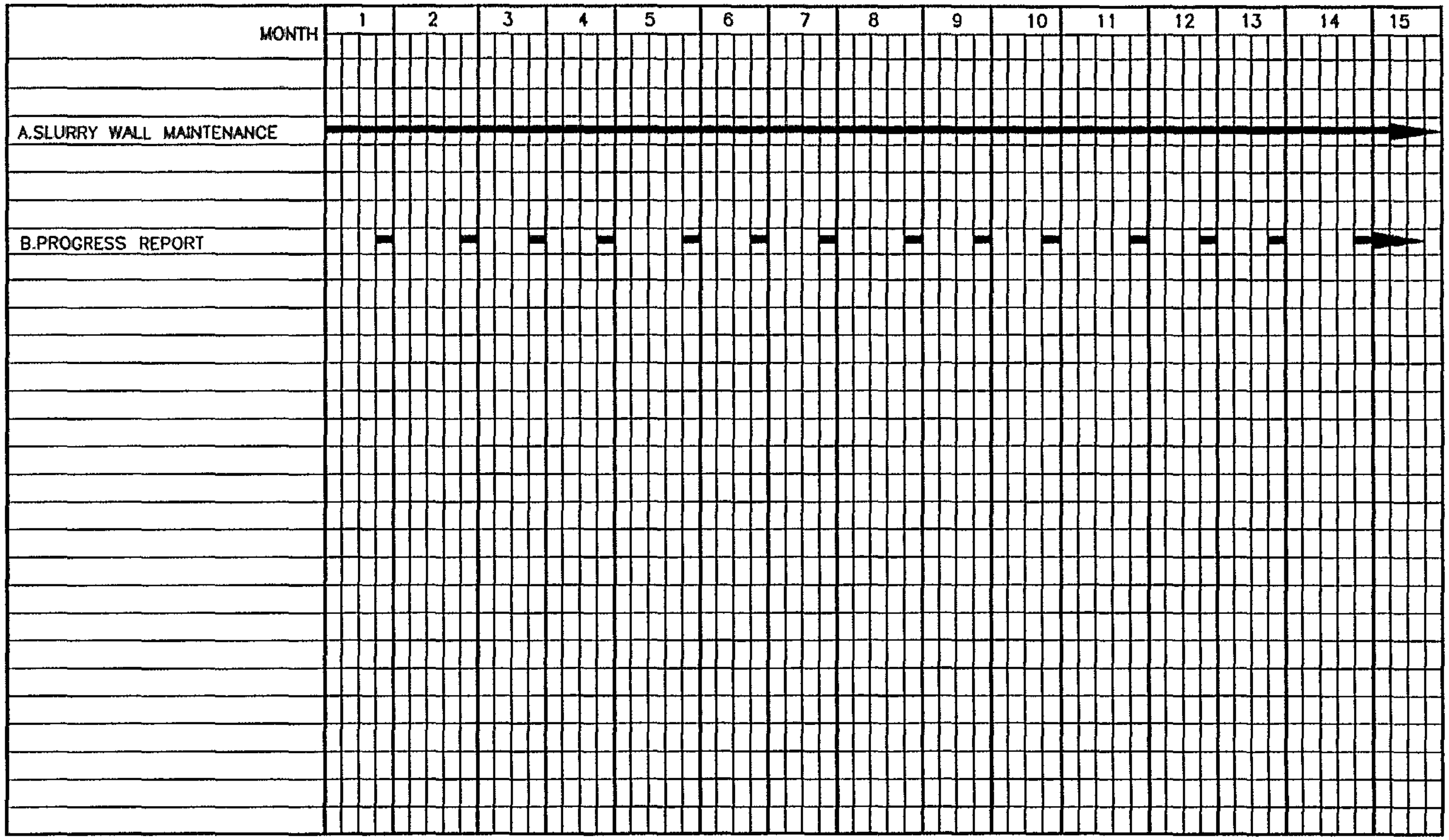
DRAFT SCHEDULE FOR SLURRY WALL CONSTRUCTION
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

DATE: 7-30-92
APP'D: J.W.

DRAWING NO.
FIGURE 4-2

ORIGINAL (Red)

AR302005



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NEW CASTLE, DELAWARE

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DRAWING
FIGURE

ORIGINAL (Red)

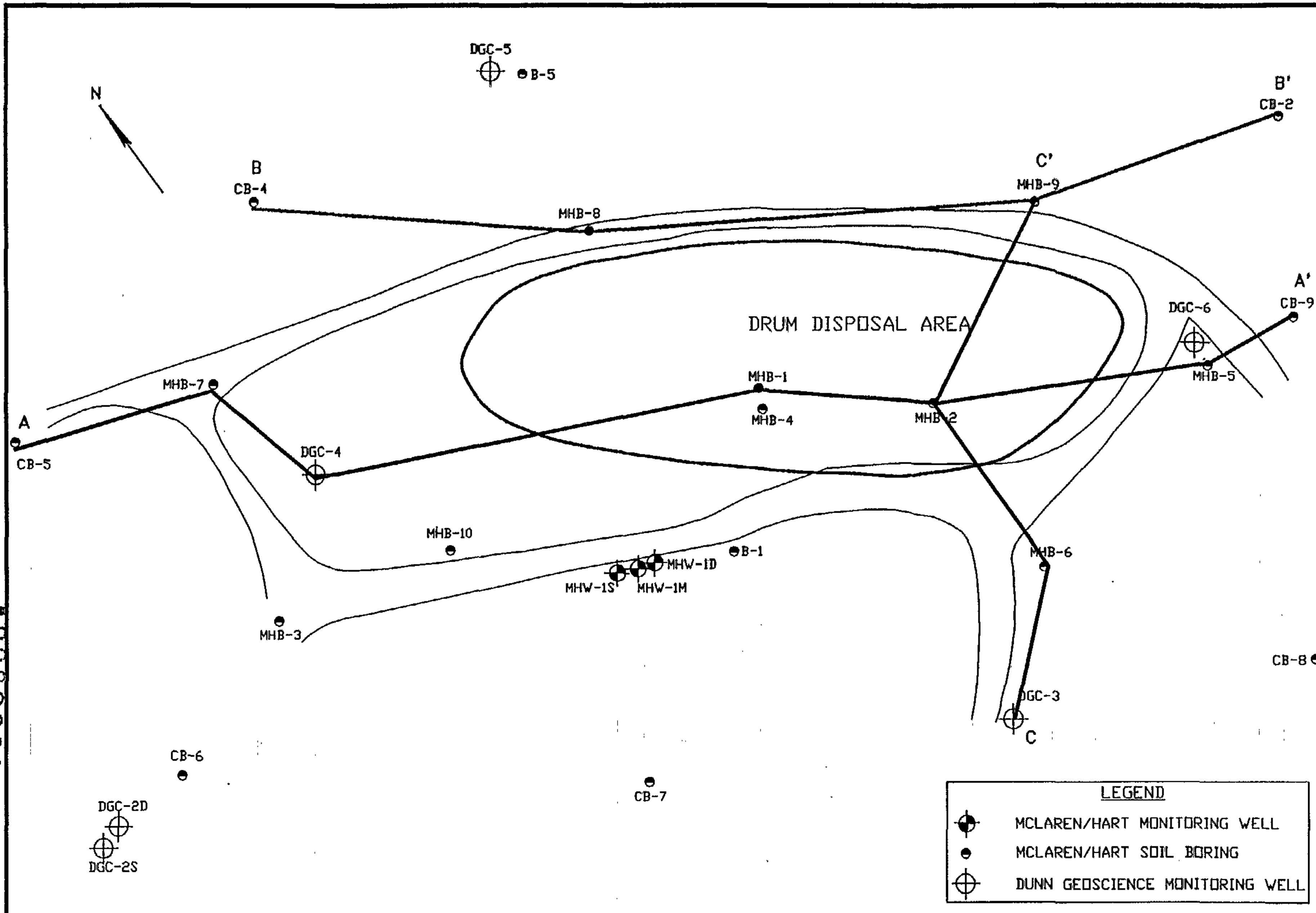
ORIGINAL (Red)

APPENDIX A

GEOLOGIC CROSS-SECTIONS

AR302007

(DSG/5-16)



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GEOLOGIC CROSS-SECTION LINES
DELAWARE SAND & GRAVEL
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DRAWING
FIGURE

ORIGINAL (Red)

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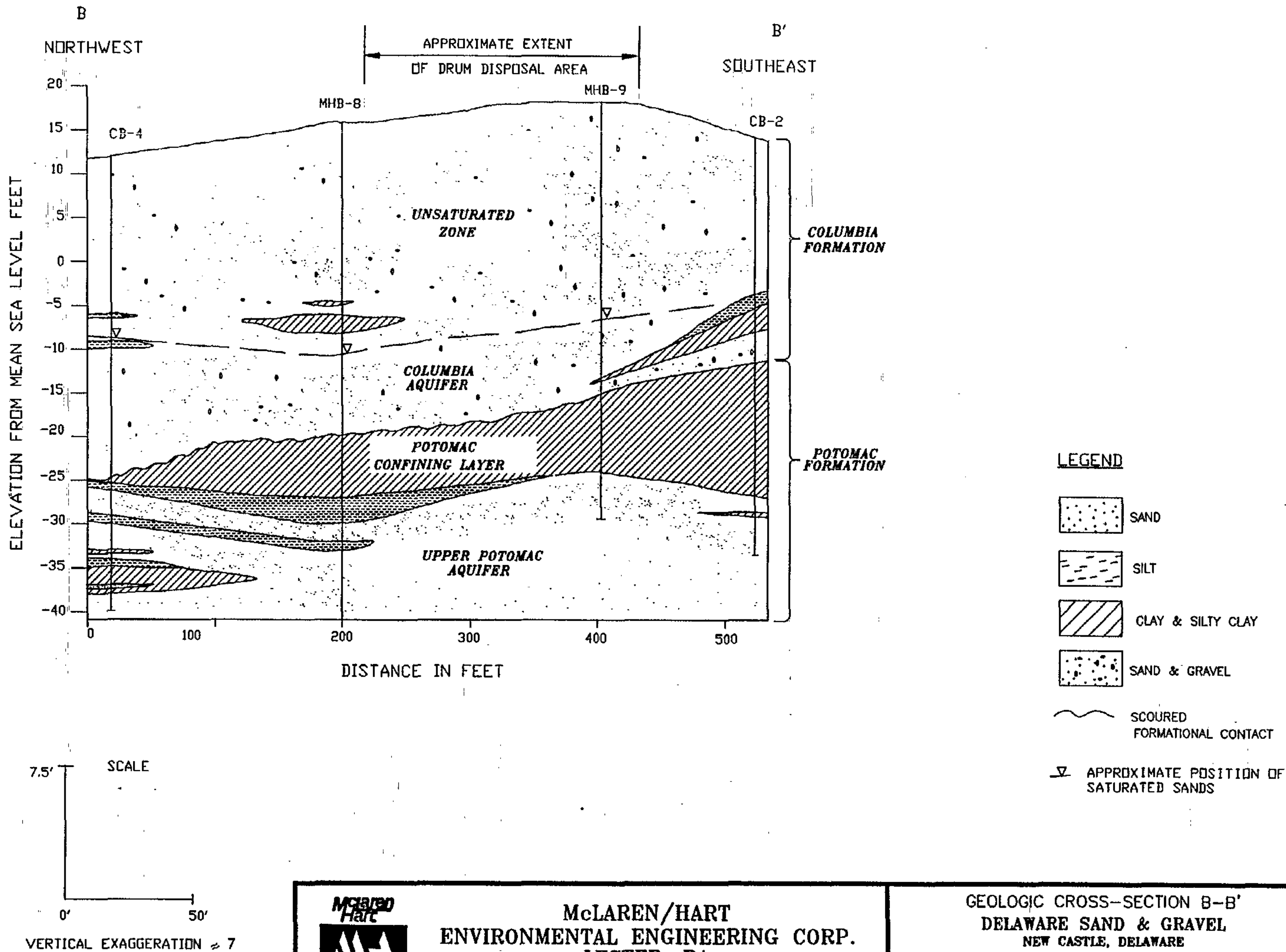

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GEOLOGIC CROSS-SECTION B-B′
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

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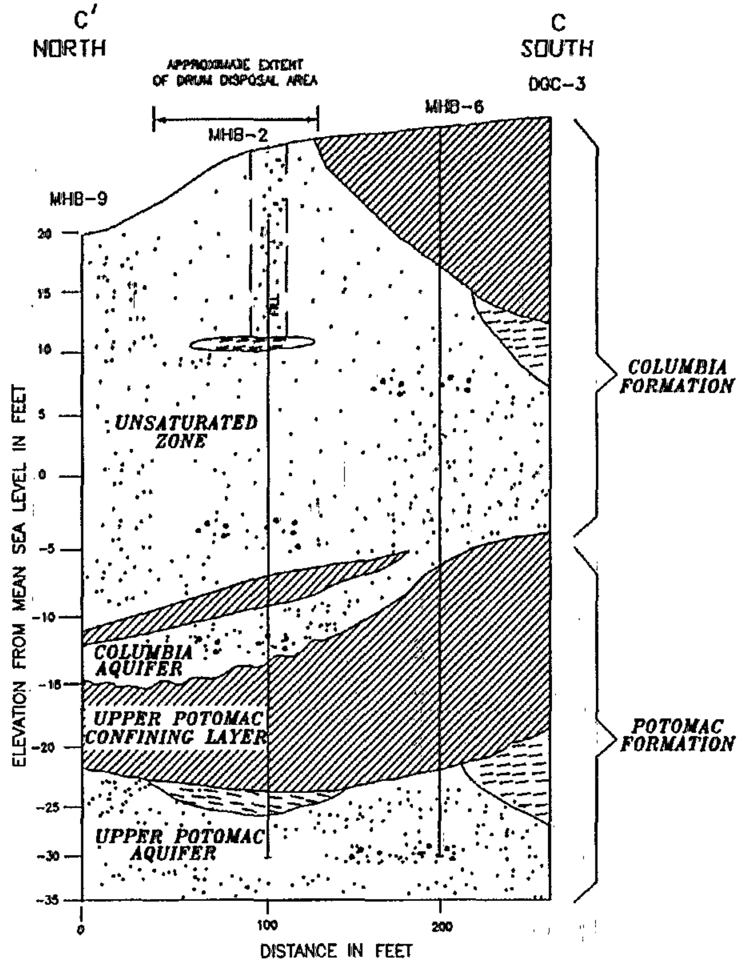
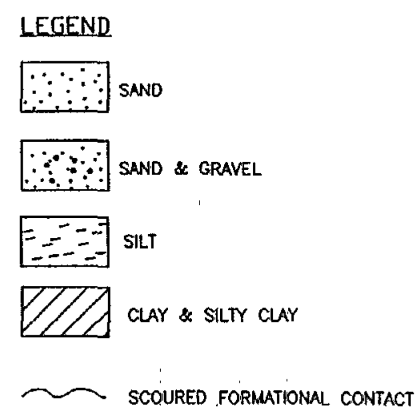
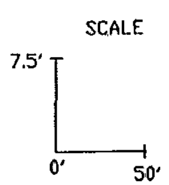
DRAWING NO.
FIGURE A-3

ORIGINAL (Red)

AR302009







VERTICAL EXAGGERATION ≈ 7

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GEOLOGIC CROSS-SECTION C-C'
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

DATE: 7-30-92
APP'D: J.W.

DRAW O.
FIGURE A-4

ORIGINAL (Red)

ORIGINAL
(Red)

APPENDIX B

QUALITY ASSURANCE PROJECT PLAN

ORIGINAL
(Red)

APPENDIX B
QUALITY ASSURANCE PROJECT PLAN
DELAWARE SAND AND GRAVEL SITE
NEW CASTLE, DELAWARE

SEPTEMBER 30, 1992

Prepared For:

Delaware Sand and Gravel Site Technical Committee

Prepared By:

McLaren/Hart Environmental Engineering Corporation
200 Stevens Drive, Suite 300
Lester, PA 19113

(DSG/7-30)

ORIGINAL (Red)

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ORIGINAL (Red)

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ORIGINAL (Red)

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1.0 PROJECT DESCRIPTION

A Response Action Plan has been prepared to fulfill the requirements of the Consent Order as specified by the U.S. Environmental Protection Agency (EPA) for the Delaware Sand and Gravel (DS&G) Site in New Castle, Delaware. EPA's specific requirements for the preparation of the Response Action Plan are set forth in Consent Order Index No. III-92-24-DC issued to DS&G Technical Committee (hereinafter referred to as the Committee) pursuant to Section 106(a) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended.

The Delaware Sand and Gravel (DS&G) Site consists of approximately 27 acres located on Grantham Lane, about 2 miles southwest of the town center of New Castle, New Castle County, Delaware. From approximately 1963 through 1976, hazardous substances were disposed of at the Site. The site contains at least four areas where hazardous substances have been disposed: the Drum Disposal Area, Inert Disposal Area, Ridge Area, and Grantham South Area. Army Creek, a tributary of the Delaware River, borders the Site to the north and west. This RAP focuses on the Drum Disposal and Inert Areas.

On or about September 9, 1968, the Delaware Water and Air Resource Commission issued to the Delaware Sand and Gravel Company, the owner and operator of the Site, a Certificate of Approval for a sanitary landfill which allowed for the disposal of cardboard, wire, pallets, corkdust, and styrofoam in the solid waste landfill.

During 1970, the Delaware Department of Natural Resources and Environmental Control (DNREC) issued a Solid Waste Disposal Permit for continued operation of the Site as a solid waste landfill, effective from 1971 to 1976.

DNREC inspected the Site during 1975 and installed groundwater monitoring wells around the site because DNREC suspected that leachate from the landfill had impacted the groundwater. Due to improper operating procedures at the Site, which included poor cover and compaction of the disposed materials on site, DNREC took a civil enforcement action against the Delaware Sand and Gravel Company during 1976 which resulted in the closure of the landfill.

ORIGINAL (Red)

During 1987, DNREC suspected that an estimated 7,500 drums containing industrial liquids and sludges from perfume, plastic, paint, and petroleum refining processes had been emptied into an unlined pit of approximately 3/4 of an acre in size and approximately 15 feet deep at the Site. This unlined pit became known as the Drum Disposal Area (DDA).

The Site was proposed for listing on the National Priorities List (NPL) in October 1981. Pursuant to Section 105 of CERCLA 42 U.S.C § 9605, EPA placed the Site on the NPL, set forth at 40 C.F.R. Part 300, Appendix B, by publication in the Federal Register on September 8, 1983 (48 Fed. Reg. 40658).

During December 1983, a Superfund Site Investigation (SI) was performed by EPA. Based on the results of the SI, EPA initiated a removal action in the Drum Disposal Area during March 1984. As part of the removal action, 1,644 drums, many of which were intact, were recovered and disposed of by EPA. The remaining drums were covered with topsoil and hydroseeded. A fence was then constructed around the perimeter to restrict unauthorized access to the Drum Disposal Area.

On April 22, 1988, a ROD was finalized for the Site.

On or about July 30, 1991 the EPA Region III Removal Branch performed an inspection of the Drum Disposal Area. EPA inspectors observed that the fence surrounding the Drum Disposal Area had been breached and that tire tracks from recreational vehicles were on top of the pit which indicated that unauthorized entry had been made into the Drum Disposal Area. Several seeps were also observed on top of the Drum Disposal Area.

On October 18, 1991, EPA issued an Administrative Order (Docket No. III-91-71-DC) pursuant to Section 106(a) of CERCLA, to Respondents which required the Respondents to construct a fence around the Drum Disposal Area to preclude access to the Drum Disposal Area. The fence was constructed by Respondents within the time frames specified in the Order. The fence which had been constructed by EPA in 1983 around the perimeter of the Drum Disposal Area had been breached and broken apart by trespassers and wildlife.

EPA is currently completing a Superfund remedial pre-design investigation of the Site. To date, the pre-design investigation has been undertaken at the Drum Disposal Area in two stages. During the summer of 1990 State One of the investigation was performed by EPA and included a magnetometer survey of the Drum Disposal Area to delineate the boundaries of the drum burial area, the excavation of six test pits at the perimeter of the Drum Disposal Area, and soil boring exploration at the perimeter of the Drum Disposal Area. The purpose of Stage One of the investigation was to define the horizontal and vertical extent of contamination in the Drum Disposal Area, and to determine the condition and the estimated quantity of wastes from drums in the Drum Disposal Area.

During Stage One of the pre-design investigation, six test pits were excavated at the perimeter of the Drum Disposal Area to further delineate the boundaries of the Drum Disposal Area. Buried, intact drums were found in these test pits at depths up to 15 feet. Twenty-three soil borings were planned for the perimeter and interior of the Drum Disposal Area in order to determine the horizontal and vertical extent of contamination. Eight soil borings were drilled around the perimeter of the Drum Disposal Area with the remaining 15 soil borings planned for the interior of the Drum Disposal Area. The 15 interior soil borings were canceled, due to safety concerns, when intact drums were encountered during the test pit excavation. As a result, the 15 borings planned for the interior were placed around the perimeter of the Drum Disposal Area along with the eight borings originally planned for the perimeter. It had previously been considered feasible to extend borings into the Drum Disposal Area without drum removal, because of the reported piercing and draining of these drums prior to disposal, making the likelihood of finding intact waste containing drums remote. However, the discovery of intact drums in the test pits rendered any soil boring exploration in the Drum Disposal Area a safety hazard.

Laboratory analysis of the perimeter test pit and boring samples detected elevated concentrations of methylene chloride, toluene, xylene, ethylbenzene, chloroform, styrene, trichloroethene and PCBs. Other volatile and semi-volatile compounds were also detected.

The wastes in the Drum Disposal Area are currently located in what is geologically known at the Columbia Formation. The Columbia Formation is comprised of sandy silts, silty sands, and

ORIGINAL (Red)

fine to coarse-grain sand with varying amounts of silt, clay, and pea-sized gravels. During Stage One of the pre-design investigation, approximately 3.7 feet of fluid was discovered in the Drum Disposal Area above the Upper Potomac Clay Layer. The Upper Potomac Clay Layer rests beneath the Drum Disposal Area and the Columbia Formation.

Based on the results of the Stage One Investigation, Stage Two of the pre-design investigation was modified to include the excavation of two trenches, to create two drum-free areas into which borings could safely be extended to characterize the soils and wastes beneath the drums in the Drum Disposal Area. Stage Two activities were performed during January and February of 1991.

During Stage Two of the pre-design investigation, two trenches were extended from the perimeter of the Drum Disposal Area to approximately 30 feet into the Drum Disposal Area. Sixty-four (64) intact or waste-containing drums were removed. Additional drums were to be removed at that time but trenching was stopped when the depth of water encountered in the excavation area made it difficult to proceed further. All sixty-four (64) drums were placed into overpack containers to contain any leakage from the drums. Of the sixty-four (64) overpacked, twenty (20) had to be overpacked into special overpacks to accommodate badly warped drums. During the trenching, rusted and leaking drums were encountered one to two feet below the surface and down to a depth of fifteen (15) feet. Many laboratory packs were found within buried, partially open drums. Leaking of drum contents was evident as indicated by stained soils. Upon completion of the trenching, drum removal, and trench sampling activities, the trenches were backfilled with clean fill.

It is evident from borings drilled during the pre-design investigation beneath and along the perimeter of the Drum Disposal Area that fluids from the pit area are leaching through the Columbia Formation sediments to the top of the relatively impermeable clay unit which caps the underlying Potomac Clay Formation. The fluids then move horizontally (sheet flow) on top of the Potomac Clay unit discharging through a zero clay area into the Upper Potomac aquifer.

During July 1991, McLaren/Hart working for the Committee, sampled thirty-three (33) of the sixty-four (64) drums which had been staged at the Site by EPA during Stage Two of the pre-design investigation. Thirty-four samples were taken and analyzed for volatile organic compounds, semi-volatile organic compounds, metals, pesticides, and PCBs. Major substances of concern which were detected include: methylene chloride, naphthalene, toluene, benzene, 2-butanone (MEK), ethylbenzene, styrene, phenol, and Aroclor-1254.

Based on the information described above, EPA determined on or about March 22, 1992, that a threat to public health or welfare or the environment exists at the Site and that a removal action is warranted. Following this determination, the Respondents received the Consent Order from EPA to construct a slurry wall around the DDA and to design a multi-layered cap for the Inert Area.

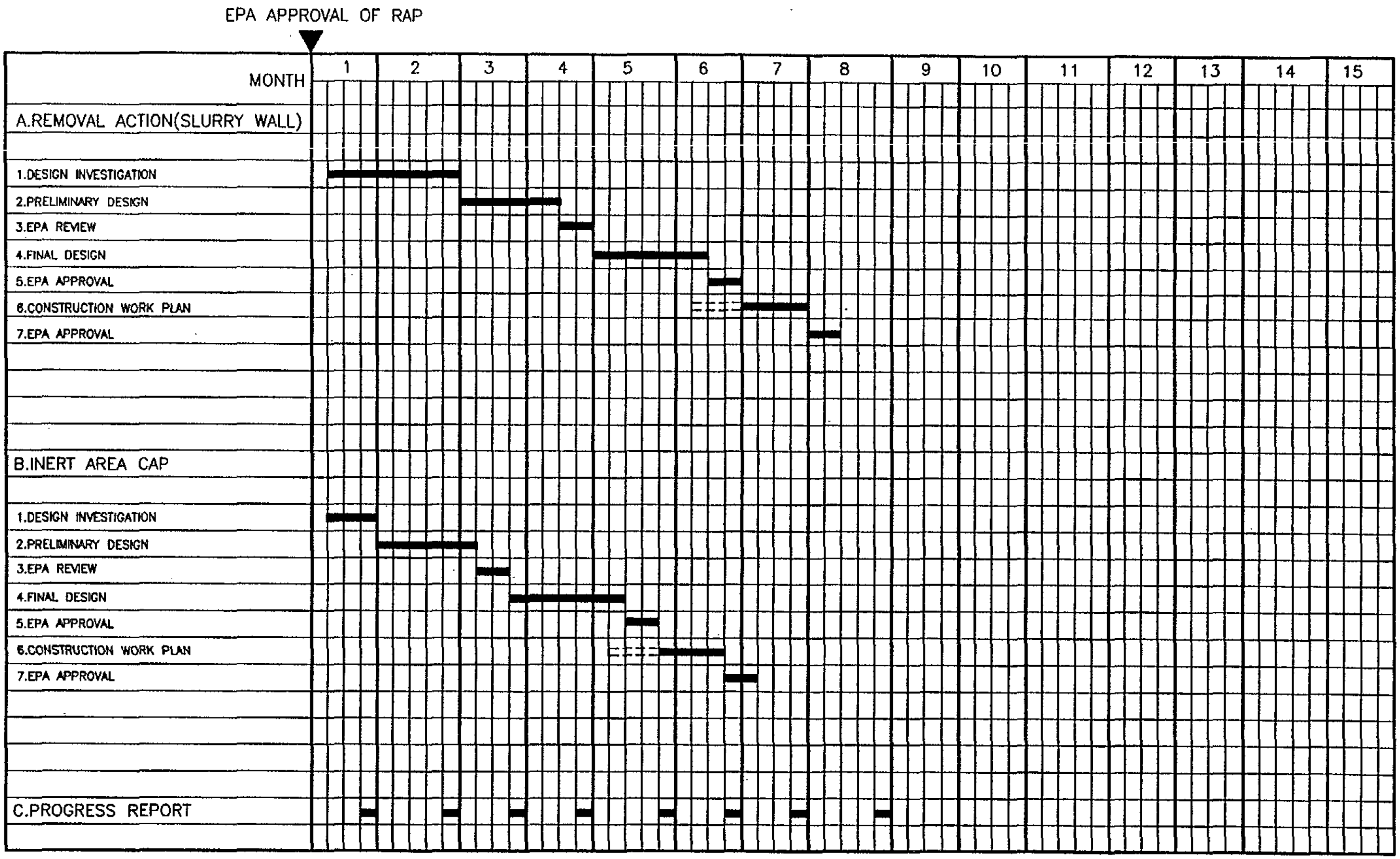
A Response Action Plan for the Site has been prepared in accordance with the requirements set forth by EPA Region III in the Consent Order. The Response Action Plan specifies the procedures, personnel, and methods which will be employed to obtain the design information necessary for implementation of the Response Action for the Site. The project activities will include geotechnical investigation for the Slurry Wall, delineation of the extent of the Inert Disposal Area, and Site Surveying.

The geotechnical investigation is designed to collect Site specific information prior to design of the slurry wall configuration. This investigation will define the following items:

- Depth to Potomac clay along slurry alignment;
- Chemical compatibility of bentonite and Site specific contaminants; and
- Appropriate soil - bentonite mix design.

The Inert Area Cap Design investigation will delineate the area limits of the Inert Disposal Area. Information derived from this study will be used for the cap design. Test borings may be installed at 200 ft. intervals around the approximate perimeter of the area, if necessary.

A proposed project schedule is included as Figure 1-1. Initiation of all phases of work are dependent on project review and approval by EPA. Further detail and rationale for the Response Action activities can be found in the Response Action Plan.



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SLURRY WALL AND INERT AREA CAP DESIGN SCHEDULE

DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

DATE: 7-30-92
APP'D: J.W.

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FIGURE 1-1

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In order to provide quality assurance (QA) and maintain quality control (QC) regarding all samples collected as part of the Response Action work, this Quality Assurance Project Plan (QAPjP) has been prepared as part of the Response Action Plan for the DS&G Site. The QAPjP has been prepared according to guidance given in EPA documents, EPA-540/G-90/004, "Quality Assurance/Quality Control Guidance for Removal Action," April 1990.

2.0 LEVEL OF ANALYTICAL SUPPORT

The level of analytical support chosen for design investigation must be carefully considered to ensure the data is of sufficiently high quality to meet the goals of the investigation. EPA's "Data Quality Objectives for Remedial Response Activities" (EPA 540-G-87-0003) discusses five general levels of analytical support (designated Level I through Level V) which may be used depending on the intended uses of the data. Two of these five levels of analytical support will be employed for this design investigation, as follows:

- LEVEL III: Laboratory analysis using methods other than the CLP RAS. This level is used primarily in support of engineering studies using standard EPA approved procedures. Some procedures may be equivalent to CLP RAS, without the CLP requirements for documentation. All grain size and permeability testing will be conducted using LEVEL III analytical support.

- LEVEL I: Field Screening. This level is characterized by the use of portable instruments which can provide real-time data to assist in the optimization of sampling point locations and for health and safety support. All routine air monitoring (as discussed in the Health and Safety Plan) will be conducted using Level I analytical support.

ORIGINAL (Red)

3.0 PROJECT ORGANIZATION AND RESPONSIBILITY

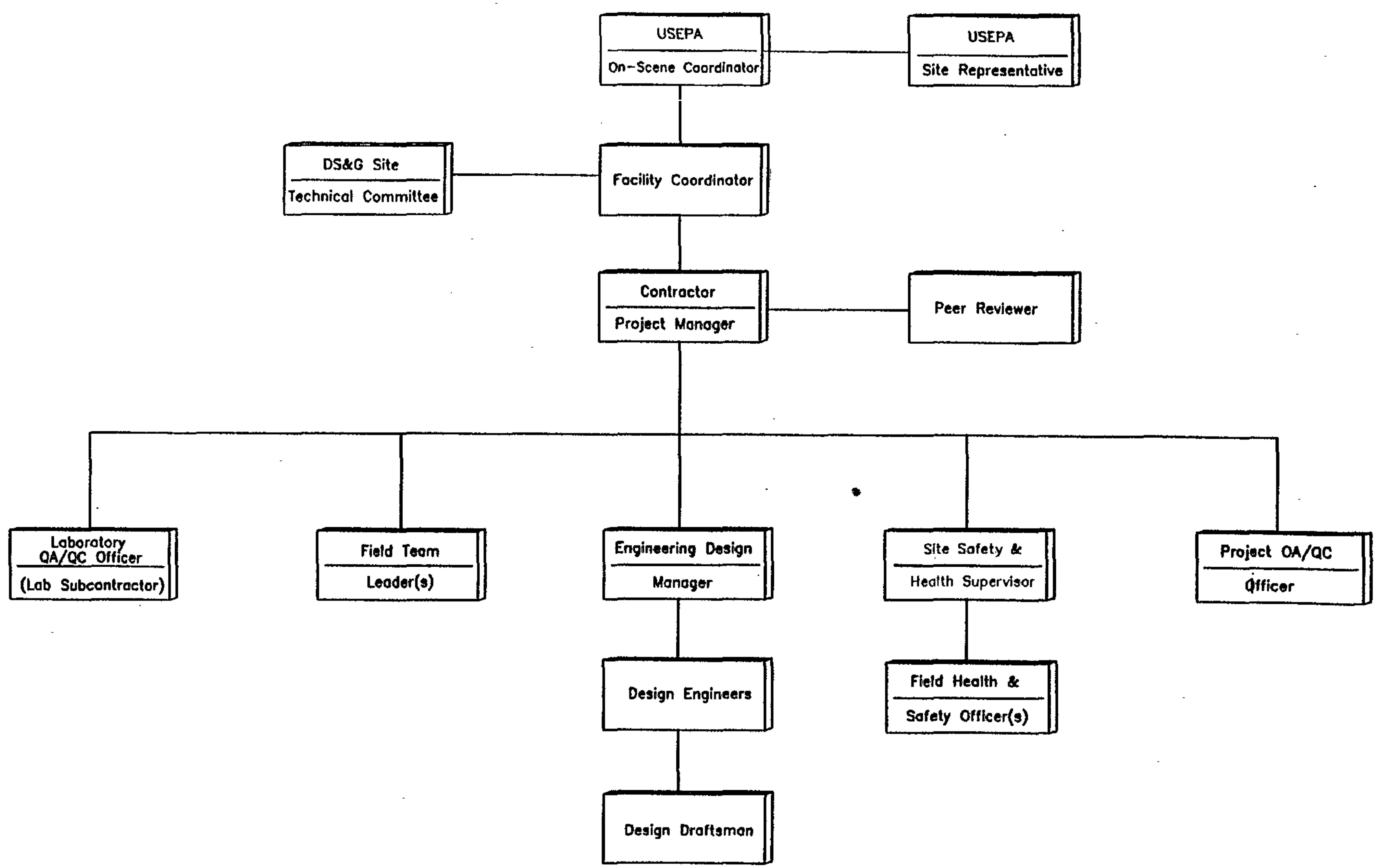
The project organizational structure is shown in Figure 3-1. This chart also depicts the organizational relationships between the Committee, the Facility Coordinator, the contractor and its subcontractors.

The individuals who are responsible for ensuring the collection of valid measurements, data and the routine assessment of measurement systems for precision and accuracy include the Project Manager, the Peer Reviewer, the Field Team Leaders, the Project QA Officer and the Laboratory QA Officer. The responsibilities of the personnel filling these five positions area described in the following subsections.

3.1 PROJECT MANAGER

The Project Manager will be responsible for coordinating implementation of the elements in the Response Action Plan. The Project Manager will serve as liaison between the Committee and the ongoing investigation. Additionally, the Project Manager will be responsible for ensuring completion of the progress reports as well as participating in all major meetings with the EPA or its contractor, as needed, during the course of the project.

The Project Manager will also be responsible for adherence to project schedules; preparation of monthly reports; development and monitoring of cost control measures; reviewing and assessing the adequacy of the performance of technical staff and laboratory subcontractors; maintaining full orderly project documentation; interacting with the Committee and EPA during the progress of the project; and managing project specific problems and issues resolutions. The Project Manager will be responsible for ensuring that EPA personnel and/or EPA authorized representatives are allowed access to the laboratory, records and personnel utilized for analyses of samples collected.



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PROJECT ORGANIZATION
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

DATE: 7-30-92
APP'D: J.W.

DRAWING NO.
FIGURE 3-1

ORIGINAL (Red)

3.2 PEER REVIEWER

The peer reviewer will be responsible for providing independent review of all project documents and reports. Principal concerns will be technical adequacy of the documents, and conformance to the approved scope of work. The peer reviewer may be employed by the contractor, but will be independent of the project team.

3.3 FIELD TEAM LEADER(S)

The field team leader(s) will be responsible for coordinating the activities of field personnel and subcontractors; adherence of the field work to project plans; documentation of field work; and management of sampling team and sampling activities from sampling to shipping. The field team leader(s) will also have supervisory authority in the event any components of the Site Health and Safety Plan has to be implemented.

3.4 PROJECT QUALITY ASSURANCE OFFICER

The Project Quality Assurance Officer will be responsible for review of field and laboratory data for compliance with QA objectives (precision, accuracy and completeness criteria) as stated in this QAPjP, and notification to the Project Manager of any QC deficiencies. The Project QA Officer will also be responsible for conducting and reporting the results of the field team performance and system audits as outlined in Section 10.2 of this QAPjP. In addition, the project QA officer will be responsible for conducting the data validation for all the testing results.

3.5 LABORATORY QUALITY ASSURANCE OFFICER

The Laboratory Quality Assurance Officer will be responsible for quality control procedures and QC checks in the laboratory and will ensure that laboratory protocols are strictly adhered to. This will be done in the form of ongoing oversight of the project, and in the firm of performance and system audits as outlined in Section 10.1 of this QAPjP.

In addition, the Laboratory QA Officer will be responsible for tracking the movement of each sample from the time the sampling program begins until the final analytical data are assembled in the report. Test result reports and data management reports, including analytical results, quality control data, chain-of-custody, the appropriate historical data, will be assembled by computer. All calculations will be given a final check by the Laboratory QA Officer.

3.6 SITE SAFETY AND HEALTH SUPERVISOR

The responsibilities of the Site Safety and Health Supervisor include implementation of the Health and Safety Plan, conducting Health and Safety audits, etc. (see Appendix C for details).

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4.0 QA OBJECTIVES FOR MEASUREMENT DATA

The overall QA objective is to develop and implement procedures for field sampling, chain-of-custody, field analysis, laboratory analysis and reporting. Specific procedures to be used for sampling, chain-of-custody, calibration, field and laboratory analysis, reporting, internal quality control, audits, preventative maintenance and corrective actions are described in other sections of this QAPjP. The characteristics of major importance to quality measurement data are accuracy, precision, completeness, representativeness and comparability.

4.1 DATA ACCURACY AND PRECISION

Accuracy is the degree of agreement of a measurement with an accepted reference or true value and is a measure of bias in a system. Precision is a measure of mutual agreement among individual measurements of the same properties and is best expressed in terms of the standard deviation or relative percent difference (RPD). QA targets for accuracy and precision are stipulated in the appropriate ASTM Standards. Replicate samples will be collected for each parameter tested.

The Coefficient of Variation (CV) is generally used in determining the accuracy and precision of the analytical data. The CV expresses the standard deviation as a percentage of the mean (average) value of the replicate values. The CV is used to determine a false positive or false negative value for results that are respectively greater than or less than a decision level concentration. The following equation is used to determine the coefficient of variation:

$$CV = (S \times 100)/X_{DL}$$

Where: X_{DL} = the decision level concentration

S = the sample standard deviation given by the equation:

$$S = [(X_i - X)^2/(n-1)]^{1/2}$$

Apply the CV to the decision level (X_{DL}) to determine the false negative or false positive value as follows:

False positive value =	Decision level value + (CV x decision level)
False negative value =	Decision level value - (CV x decision level)

4.2 DATA COMPLETENESS

Based on our present knowledge of Site accessibility, it is believed that 100 percent of the proposed samples can be collected. It is expected that the laboratory will provide data meeting QC acceptance criteria for 95 percent or more of all samples analyzed. Laboratory data will be reviewed by the laboratory and project QA officer for completeness.

4.3 DATA REPRESENTATIVENESS

The ultimate success of the Response Action Plan for slurry wall design and construction and the Inert Area cap design is dependent upon the collection of representative data. Concerns regarding data representativeness include the following:

- number and location of data collection points (test borings);
- choice of parameters for physical analyses;
- frequency of data collection; and
- choice of specific technologies for data collection.

As each phase of the SAMP is introduced (Section 2.4 of the Response Action Plan), the rationale and objectives for that phase are discussed. Included in these discussions are presentations of how each element of the SAMP was designed and will be implemented in order to obtain physical data sets that are representative of Site conditions.

4.4 DATA COMPARABILITY

The methods used for the collection and analysis of soil samples from this Site, as documented in the Response Action Plan, SAMP and this QAPjP, are based on currently accepted procedures outlined in most recent ASTM Standards. As such, all results from this investigation are expected to provide comparable data. Geotechnical soil sample results will be reported in the units specified by the ASTM methods employed.

5.0 SAMPLING, TESTING, FIELD MEASUREMENTS PROCEDURES

5.1 SAMPLING AND TESTING PROCEDURES

Procedures for collecting soil samples for geotechnical analysis during the Response Action Plan to be conducted at this Site are described in Section 2.4 of the Sampling, Analysis and Monitoring Plan. All samplers will use and change disposable gloves between sampling points. Specific procedures for sampling equipment decontamination and acceptable sampling conditions are discussed in Section 2.4.1 of the Field Sampling Plan.

Test boring locations and sampling intervals for the Drum Disposal Area and Inert Area are provided in Section 2.4.1 of the Response Action Plan.

Geotechnical testing of soil samples will be performed according to appropriate ASTM and Army Corps of Engineers methods. Geotechnical analyses will include grain size analysis by ASTM Method 422, permeability test by ASTM Method D5084-90, Moisture Content Test by ASTM Method D2216 and Atterberg Limit test by ASTM Method D4318. Sample volume, containers, preservation, and holding times for each analytical parameter are specified in Table 5-1.

5.2 FIELD MEASUREMENTS

Field instrumentation used during the investigation phase of the Response Action Plan will be limited to an HNu Photoionization meter used for air monitoring and screening geotechnical soil samples. Procedures for field screening with the HNu model PI 101 portable photoionization meter are described in Section 2.4 of the Sampling, Analysis and Monitoring Plan.

Detailed procedures for equipment calibration, maintenance and use are provided in Appendix A of this document. Field personnel will familiarize themselves with the operational guidelines of the HNu prior to use, to ensure that representative measurements are collected. Particular attention will be given to the functional limitations of each instrument under adverse field conditions.

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TABLE 5-1 SAMPLE COLLECTION REQUIREMENTS				
Parameter	Matrix	Sample Preservation	Holding Time	Volume/ Container
Grain Size	Soil	NA	NA	Entire volume of 3" O.D. sampler
Permeability	Soil	NA	NA	Plastic Bag
Moisture Content	Soil	NA	NA	Glass jar
Atterbert Limit	Soil	NA	NA	Entire volume of 3" O.D. sampler

NA - Not Applicable

ORIGINAL (Red)

6.0 SAMPLE HANDLING, SHIPPING AND CUSTODY

6.1 FIELD DOCUMENTATION

Following sampling, the sealed sample container will be cleaned with moist paper towels, dried and labeled. Sampling containers that have been immersed in fluid will be rinsed with tap water, dried and labeled. The sample labels will contain, at a minimum, the following information:

- Media;
- Sample ID Number;
- Sample Location;
- Name of Sampling Personnel;
- Name of Sampling Organization;
- Data and Time Sampled;
- Type of Preservative, if any; and
- Analysis Requested.

Sample labels shall be completed in waterproof ink and covered with clear tape.

A chain-of-custody form will be maintained for each sample collected. The chain-of-custody procedures will provide accurate written records which can be used to trace the possession and holding of samples from the time of collection through data analysis and reporting. The following information will be specified for each sample on the chain-of-custody form: 1) sequential sample number; 2) sample media; 3) sample date and time; 4) sample location; and 5) analysis requested. A sample chain-of-custody form is provided in Figure 6-1.

A chain-of-custody form will be signed by each participant. The forms will be placed in a water tight plastic bag and taped to the underside of the lid of the cooler containing the samples designated on the form. The lid of the cooler will be secured with nylon strapping tape and

ORIGINAL
(Red)

Name: ______
Affiliation: ______
Phone: ______
Address: ______
Client/Job No: ______
Job Name: ______ Location: ______

CHAIN OF CUSTODY RECORD

Sample No.	Lab I.D. No.	Date	Time	Matrix	No. of Containers	Analysis Requested/Remarks

Comments: ______

Relinquished by: ______ Date: ______ Shipment Method: ______
Time: ______ Airbill No.: ______

Received by: ______ Date: ______ Relinquished by: ______ Date: ______
Time: ______ Time: ______

Received by: ______ Date: ______ Relinquished by: ______ Date: ______
Time: ______ Time: ______

Final Disposition of Samples: ______

Received by: ______ Date: ______ Time: ______

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LESTER, PA

SAMPLE CHAIN OF CUSTODY FORM
DELAWARE SAND & GRAVEL
NEW CASTLE, DELAWARE

DATE: 7-30-92
APP'D: J.W.

DRAWING NO.
FIGURE 6-1

AR302034

custody seals. Sample coolers will be shipped the same day as sampling for next day delivery to the geotechnical testing laboratory.

Field log books will provide the means of recording data collection activities performed. Entries into the field log book will be described in as much detail as possible so that persons going to the Site could reconstruct a particular situation without reliance on memory.

Field log books will be bound field survey notebooks. Log books will be assigned to field personnel but will be stored in the field project file when not in use. Each log book will be identified by a project specific number. The title page of each notebook will contain: 1) person or organization to whom the book is assigned; 2) the book number; 3) project name; and 4) start and end dates.

Measurements made and samples collected will be recorded in field log books. All entries will be made in waterproof ink and no erasures will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark and initialed. Whenever a sample is collected or a measurement is made, a detailed description of the location of the station, which includes compass and distance measurements will be recorded. The number of photographs taken of the station will also be documented. All equipment used to make measurements will be identified, along with the date and person doing the calibration. All persons involved with the sampling must be identified in the field log book.

6.2 LABORATORY DOCUMENTATION

Upon arrival at the laboratory, samples will be checked in by the laboratory representative. All samples contained in the shipment will be compared to the chain-of-custody form to ensure that all samples designated have been received. Sample custody within the laboratory includes:

- Identification of responsible party to act as sample custodian at the laboratory facility authorized to sign for incoming field samples, obtain documents of shipment and verify the data entered onto the sample custody records.

- Provisions for a laboratory sample custody log consisting of serially numbered standard lab-tracking report sheets.

ORIGINAL (Red)

- Specifications of laboratory sample custody procedures for sample handling, storage and dispersement for analysis.

All geotechnical samples will be retained by the laboratory for a period of three months after analysis or until permission to discard is received to provide an opportunity for retesting, if necessary.

6.3 PROJECT DOCUMENTATION

A project file will be maintained by the Project Manager which will contain complete project documentation. This file will include: project plans and specifications; field log books and data records; photographs; maps and drawings; sample identification documents; chain-of-custody records; the entire analytical data package provided by the laboratory including QC documentation; copies of raw data computer printouts; references and literature; report notes and calculations; progress and technical reports; correspondence; and other pertinent information.

ORIGINAL (Red)

7.0 EQUIPMENT CALIBRATION AND MAINTENANCE

A maintenance, calibration and operation program is implemented to ensure that routine calibration and maintenance is performed on all field instruments. The program provides equipment of the proper type, range, accuracy and precision to provide data compatible with the specified requirements and desired results. Calibration of measuring and test equipment is performed internally using in-house reference standards or externally by agencies or manufacturers.

7.1 RESPONSIBILITY

The project quality assurance officer is responsible for ensuring that the field instruments used in the design investigation are calibrated and maintained according to manufacturers specifications. Field instrument manuals describing calibration, maintenance and field operating procedures for these instruments are provided in Appendix A for easy reference by field personnel and government project personnel.

Team members shall be familiar with the field calibrations, operation and maintenance of the equipment, and will perform the prescribed field operating procedures outlined in the operation and field manuals accompanying the respective instruments. They will keep records of all field instrument calibrations and field checks in the field log books.

7.2 CALIBRATION

The HNu meter will be calibrated on a daily basis prior to the start of field activities. Instrument calibration will be done in accordance with the instruction manuals provided in Appendix A.

If on-site monitoring equipment should fail, calibration and/or become inoperable, the Site Safety and Health Supervisor will be contacted immediately and will either provide replacement equipment or have the malfunction repaired immediately.

Records shall be prepared and maintained for the HNu to indicate that established calibration procedures have been followed (e.g., results of calibration, problems, corrective action). Records for field equipment used only for this specific project shall be kept in the project files.

7.3 PREVENTATIVE MAINTENANCE

Periodic preventive maintenance is required for sensitive equipment. Instrument manuals are kept on file for reference purposes should equipment need repair. Troubleshooting sections of manuals are often useful in assisting personnel in performing maintenance tasks (see Appendix A).

8.0 DATA REDUCTION, VALIDATION AND REPORTING

The laboratory will review appropriate quality control data to assure the validity of the analytical results. The analytical laboratory will prepare and retain full testing and QC documentation. Such documentation need not be hard copy, but may be in other storage media (e.g., magnetic tape). The analytical laboratory will supply one hard copy of the analytical and QC documentation to the A/E Contractor for storage in the project file. This hard copy will be in the form of a final report.

The laboratory will provide the following information in each data package they submit:

- Testing methods and results for submitted samples, with appropriate data quality notations.

- Narrative including statement of samples received, descriptions of any deviation, explanation of qualifications regarding data quality and other significant items encountered during analysis.

Data assessment will be accomplished by the joint efforts of the Project QA Officer and Project Manager. The data assessment by the Project Manager will be based on the criteria that the sample was properly collected and handled according to the sampling plans and this QAPjP.

The Project QA Officer will conduct a systematic review of the data for compliance with the established QA/QC criteria. An evaluation of data accuracy, precision, sensitivity and completeness will be performed.

The Project QA Officer will identify any out-of-control data points and data omissions and interact with the laboratory to correct data deficiencies. Decisions to repeat sample collection and analyses may be made by the Project Manager based on the extend of the deficiencies and their importance in the overall context of the project.

The Project QA Officer will provide data validation for 100% of the testing performed by the laboratory. This data validation will determine data usability and will be performed in accordance with the appropriate EPA and ASTM guidance documents for data review. For methods lacking QA/QC data validation protocols, the Project QA Officer will establish validation criteria. The appropriate quality assurance data validation summary reports will be submitted, along with sample data and summary sheets, to the EPA On-Scene Coordinator at the time final sample results are provided to EPA.

Laboratory will make available to EPA the results of all validated sampling and/or tests or other data generated by laboratory in conducting the work. EPA will have the option to revalidate some or all of this data.

Following data review, all data generated from the laboratory will be entered into a computer in a format organized to facilitate data review and evaluation.

The laboratory data set will be available for controlled access by the Project Manager and other authorized personnel. The completed data set will be incorporated into the design report.

The following EPA guidance document will be used for data validation:

- Quality Assurance/Quality Control Guidance for Removal Activities (April, 1990).

9.0 LABORATORY INTERNAL QUALITY CONTROL CHECKS

The laboratory selected to conduct analyses of samples taken at the Site must have a documented Quality Assurance Program that complies with applicable EPA and ASTM guidance documents. Geotechnical testing will be performed in accordance with the procedures specified in the most current ASTM Standards. It will be the responsibility of the laboratory, specifically the laboratory QA officer to document, in each data package provided, that both initial and ongoing instrument and testing QC functions have been met.

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10.0 PERFORMANCE AND SYSTEM AUDITS

10.1 LABORATORY PERFORMANCE AND SYSTEMS AUDITS

The laboratory will conduct internal quality control checks (replicates, blank and duplicates) in accordance with specific methods and criteria required by the appropriate testing procedures. Procedures for laboratory performance and system audits will be outlined in the Laboratory Quality Assurance Plan. The laboratory QA Officer will be primarily responsible for conducting these audits.

10.2 FIELD TEAM PERFORMANCE AND SYSTEMS AUDITS

The Project QA Officer will be responsible for conducting two audits: a performance audit and an evidence audit. The audits will evaluate the implementation of the project QA program.

The performance audit will be conducted early in the design investigation to ensure that proper procedures are followed and that subsequent data will be valid. It will focus on the details of the QA program. The audit checklist, which begins on the following page, will serve as the guide for the performance audit for field procedures. The audit will evaluate the following:

- Project Responsibilities;
- Sample Custody Procedures;
- Document Control;
- Sample Identification System; and
- QC Corrective Action Procedures.

The QA Officer will also be responsible for conducting one evidence audit. The purpose of the evidence audit is to ensure that proper project documentation is maintained. An example of an evidence audit checklist follows the audit checklist. This document will serve as the guide for the evidence audit.

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FIGURE 10-1
PERFORMANCE AUDIT CHECKLIST

DELAWARE SAND & GRAVEL SITE
NEW CASTLE, DELAWARE

Field Investigation Audit

Project No.: ______________________________ Date: ______________________

Project Location: __________________________ Signature: __________________

Team Members: ____________________________

Yes __ No __ 1. Has a project field coordinator been appointed?

Comments ____

____

____

Yes __ No __ 2. Was a project plan prepared?

Comments ____

____

____

Yes __ No __ 3. Was a briefing held for project participants?

Comments ____

____

____

Yes __ No __ 4. Were additional instructions given to project participants?

Comments ____

____

____

ORIGINAL (Red)

FIGURE 10-1
PERFORMANCE AUDIT CHECKLIST
(continued)

DELAWARE SAND & GRAVEL SITE
NEW CASTLE, DELAWARE

Yes __ No __ 5. Is there a written list of sampling locations and descriptions?

Comments ______________________________

____

____

Yes __ No __ 6. Is there a list of accountable field documents checked out to the field coordinator?

Comments ______________________________

____

____

Yes __ No __ 7. Is the transfer of field documents from the coordinator to field participants documented in a logbook?

Comments ______________________________

____

____

Yes __ No __ 8. Are samples collected as stated in the project plan or as directed by the coordinator?

Comments ______________________________

____

____

ORIGINAL (Red)

FIGURE 10-1
PERFORMANCE AUDIT CHECKLIST
(continued)

DELAWARE SAND & GRAVEL SITE
NEW CASTLE, DELAWARE

Yes __ No __ 9. Are samples collected in the type of containers specified in the project plan or as directed by the coordinator?

Comments ______________________________

____

____

Yes __ No __ 10. Are samples preserved as specified in the project plan or as directed by the coordinator?

Comments ______________________________

____

____

Yes __ No __ 11. Are the number, frequency, and type of samples collected as specified in the project plan or as directed by the coordinator?

Comments ______________________________

____

____

Yes __ No __ 12. Are the number, frequency, and type of measurements and observations taken as specified in the project plan or as directed by the coordinator?

Comments ______________________________

____

____

ORIGINAL (Red)

FIGURE 10-1
PERFORMANCE AUDIT CHECKLIST
(continued)

DELAWARE SAND & GRAVEL SITE
NEW CASTLE, DELAWARE

Yes __ No __ 13. Are samples identified with sample tags?

Comments ______________________________

____

____

Yes __ No __ 14. Are blank and duplicate samples properly identified?

Comments ______________________________

____

____

Yes __ No __ 15. Are sample and serial numbers for samples split with other organizations recorded in a logbook or on a chain-of-custody record?

Comments ______________________________

____

____

Yes __ No __ 16. Are samples listed on a chain-of-custody record?

Comments ______________________________

____

____

Yes __ No __ 17. Is chain-of-custody documented and maintained?

Comments ______________________________

____

____

ORIGINAL
(Red)

FIGURE 10-1
PERFORMANCE AUDIT CHECKLIST
(continued)

DELAWARE SAND & GRAVEL SITE
NEW CASTLE, DELAWARE

Yes __ No __ 18. Are quality assurance checks performed as directed?

Comments ______________________________

____

____

Yes __ No __ 19. Are photographs documented in logbooks as required?

Comments ______________________________

____

____

Yes __ No __ 20. Have any accountable documents been lost?

Comments ______________________________

____

____

Yes __ No __ 21. Have any accountable documents been voided?

Comments ______________________________

____

____

Yes __ No __ 22. Have any accountable documents been disposed of?

Comments ______________________________

____

____

ORIGINAL (Red)

FIGURE 10-2
EVIDENCE AUDIT CHECKLIST

DELAWARE SAND & GRAVEL SITE
NEW CASTLE, DELAWARE

Document Control Audit

Project No.: ______________________

Project Location: ______________________ Date: ______________________

File Location: ______________________ Signature: ______________________

Yes __ No __ 1) Have the individual files been assembled (field investigation, laboratory)?

Comments ______________________

____

____

Yes __ No __ 2) Is there a list of accountable field documents?

Comments ______________________

____

____

Yes __ No __ 3) Are all accountable field documents present or accounted for? (Fill out additional checklist.)

Comments ______________________

____

____

11.0 PREVENTIVE MAINTENANCE

For preventative maintenance procedures in the field, see Appendix A. Preventative maintenance procedures for laboratory instruments will be provided in the Laboratory Quality Assurance Plan.

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12.0 SPECIFIC ROUTINE PROCEDURES TO ASSESS PRECISION, ACCURACY AND COMPLETENESS OF DATA

The procedures for assessing the precision, accuracy and completeness of data have been presented in previous sections of this QAPjP (Sections 4.1 and 4.2). It will be the responsibility of the Project QA Officer and the Laboratory QA Officer to ensure that these procedures are followed.

13.0 CORRECTIVE ACTION

Corrective action on a day-to-day basis for field sampling will be handled by consultation between team members and the team leader. The team leader will make immediate decisions with the team members on new protocols to be followed. All changes in field sampling procedures will be documented in the field logbook and reported to the Project QA Officer and in the final report. The field team leader will make decisions concerning Site safety emergencies without further consultation.

Corrective action in the laboratory will be handled by consultation between the Laboratory QA Officer and the Project QA Officer. All changes in laboratory procedures will be documented in the final report. In addition, the limits for data acceptability, beyond which corrective action is required, will be determined by the Laboratory QA officer and the Project QA officer prior to the sample testing.

14.0 QUALITY ASSURANCE REPORTS TO MANAGEMENT

Monthly reports will be issued by the Project Manager in consultation with the Field Team Leader and the Project QA Officer. The reports will include assessment of the status of the project in relation to the agreed upon timetable. The reports will also include, as appropriate, the results of the performance audit, any necessary corrective action procedures, ~~and~~ a periodic assessment of measurement data accuracy, any nonconfirmances identified, and any significant change to QAPjP precision and completeness.

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ATTACHMENT A

FIELD INSTRUMENT INSTRUCTION MANUALS

INSTRUCTION MANUAL

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MODEL PI 101

Portable Photoionization Analyzer

hnu

AR302054

INSTRUCTION MANUAL

TRACE GAS ANALYZER

HNU MODEL PI 101

HNU Systems, Inc.
160 Charlemont St.
Newton, MA 02161

December 1985

TABLE OF CONTENTS cont.

ORIGINAL (Red)

LIST OF ILLUSTRATIONS

LIST OF TABLES

WARNINGS

The following warnings appear in this manual and are repeated here for emphasis.

Do not look at the light source from closer than 6 inches with unprotected eyes. Observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

The instrument measures gases in the vicinity of the operator and a high reading when measuring toxic or explosive gases should be cause for immediate action for safety.

Extreme care must be taken in the handling of gas cylinders. Contents are under high pressure. In some cases, the contents may be hazardous. Many gas suppliers will provide data sheets for the mixtures upon request.

Never open the valve on a gas container without a regulator attached.

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltages of 1200 V DC, will be present.

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

Be very careful to note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

The PI 101 is suitable for uses in Class I Division II ABCD areas except when using charger or when using recorder.

The PI 101 is a non-destructive analyzer; work in a hood if toxic or hazardous gases are used. In the interest of greater international acceptance the HNU Model PI 101-100 Photoionizer has been certified by Sira Safety Services Ltd. to conform to Article 501-3 of the National Electrical Code to be non-incendiary for Class 1 Division 2, Groups A, B, C and D locations Effective July 25, 1984.

SIRA Approval #APL/33/84

SECTION 1

GENERAL INFORMATION

1.1 INTRODUCTION

This manual describes the operation, maintenance and parts list for the Trace Gas Analyzer, Model PI 101, HNU Systems Inc.

1.2 EQUIPMENT DESCRIPTION

The Trace Gas Analyzer (see Figure 1-1), is a portable instrument used to detect, measure, and provide a direct reading of the concentration of a variety of trace gases in many industrial or plant atmospheres. The analyzer employs the principle of photoionization. This process involves the absorption of ultra-violet light (a photon) by a gas molecule leading to ionization:

$$RH + hv \rightarrow RH^+ + e^-$$

in which

RH = Trace gas
hv = Photon with an energy level equal to or greater than the ionization potential of RH.

The sensor consists of a sealed ultraviolet (UV) light source that emits photons with an energy level high enough to ionize many trace species, particularly organics, but not high enough to ionize the major components of air, O_2, N_2, CO, CO_2 or H_2O.

A chamber exposed to the light source contains a pair of electrodes, one a bias electrode and the second a collector electrode. When a positive potential is applied to the bias electode a field is created in the chamber. Ions formed by the absorption of photons are driven to the collector electrode. The current produced is then measured and the corresponding concentration displayed on a meter directly in parts per million (ppm).

To minimize absorption or decomposition of sample gases, a rapid flow of sample gas is maintained thru the ion chamber, which is small, made of inert material and located at the sampling point.

The analyzer consists of a probe, a readout assembly, and a battery charger. The probe contains the sensing and amplifying circuitry; the readout assembly contains the meter, controls, power supply and rechargeable battery. The analyzer will operate from the battery for more than 10 hours or continuously when connected to the battery charger.

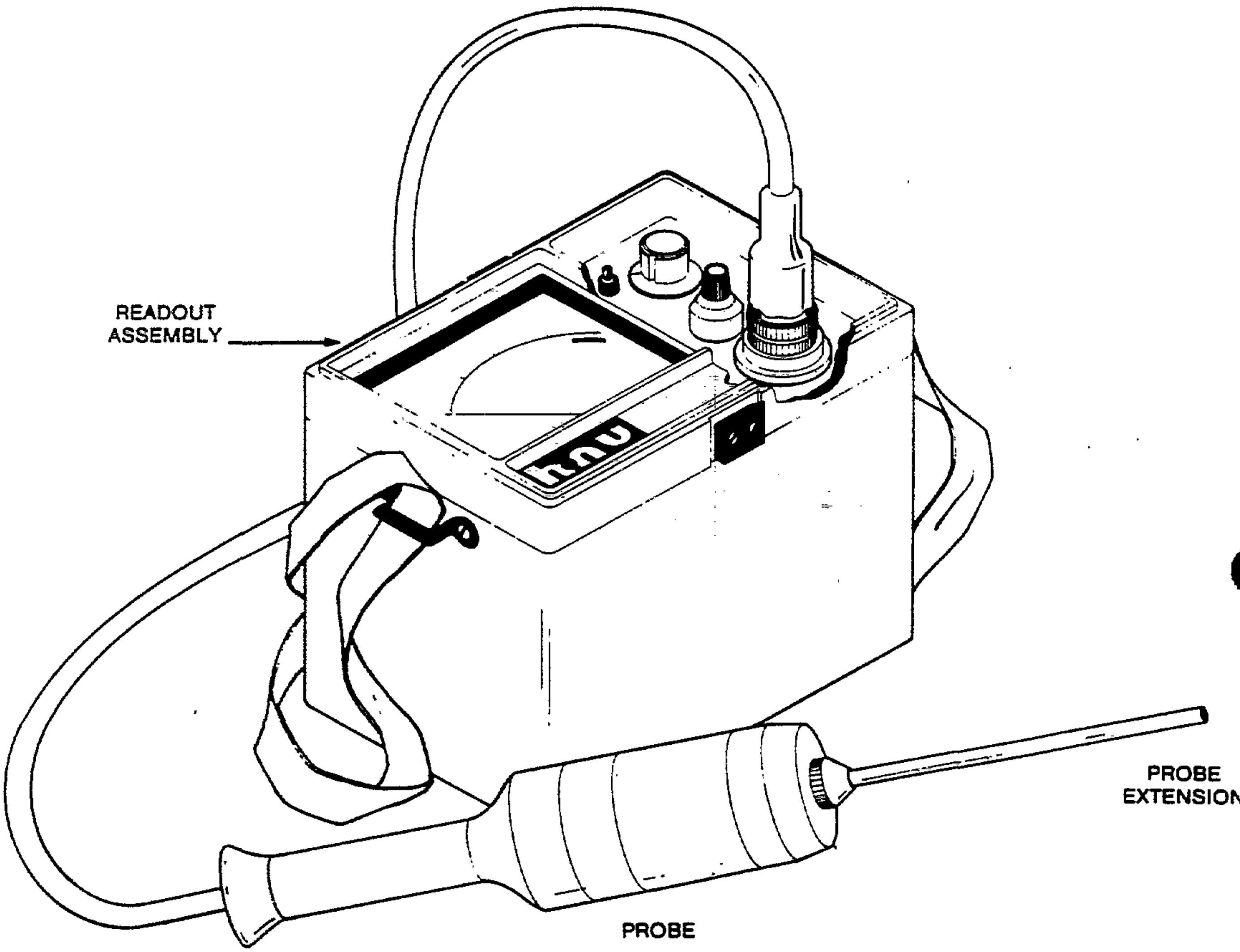

FIGURE 1-1
TRACE GAS ANALYZER
OPERATING CONDITION

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The PI 101 is designed for use with interchangeable probes with lamps of different energies. The analyzer is ready for use simply by connecting the probe to the readout assembly, setting the proper SPAN pot value, and then zeroing the unit. Specific data is given in the calibration memo accompanying each probe.

The standard probe uses a 10.2 eV lamp. Two optional probes use 9.5 and 11.7 eV lamps. Lamps of different eV ratings, ion chamber and amplifiers are not interchangeable between probes.

Many applications make use of the principle that some compounds respond to the more energetic lamps and not to others. Figure 1-2 shows the responses for the analyzer with each of the three lamps. Literature explaining several such applications is available from HNU Systems Inc.

An optional audible alarm is available giving an 85 decibel signal when a set concentration is exceeded. The alarm setting is variable and can be set from 0 to 100% of full scale of the meter reading. Power for the alarm is provided by the battery and does not significantly affect the rated use time of the analyzer. The alarm is non-latching and is set by a screw adjustment, preventing inadvertent changes.

When in the stored condition, the probe is contained in the instrument cover (see Figure 1-3) which attaches to the readout assembly to form a single unit (see Figure 1-4).

An optional recorder is available that can be directly attached to the readout assembly. It uses impact paper with a 2" wide chart and a speed of 2"/hour. The recorder is powered by the instrument battery and provides hard copy of the data. The analyzer will operate for approximately 4 hours with the recorder attached. Mounting information and illustration is given in Section 8.

Specification data on the analyzer is given in Table 1-1. Physical characteristics of the equipment are given in Table 1-2.

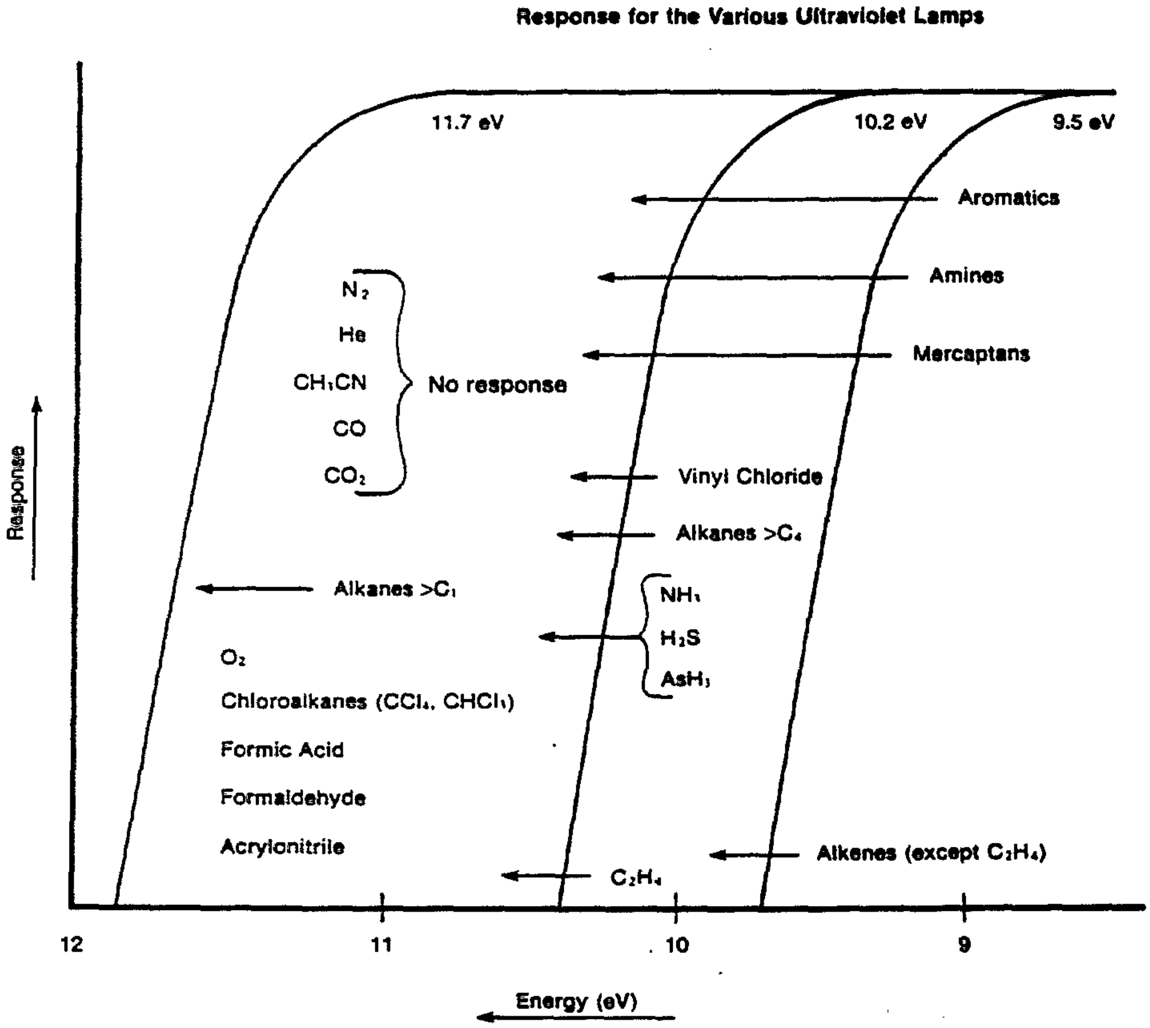

FIGURE 1-2
RESPONSE TO VARIOUS COMPOUNDS
FOR EACH ULTRAVIOLET LAMP

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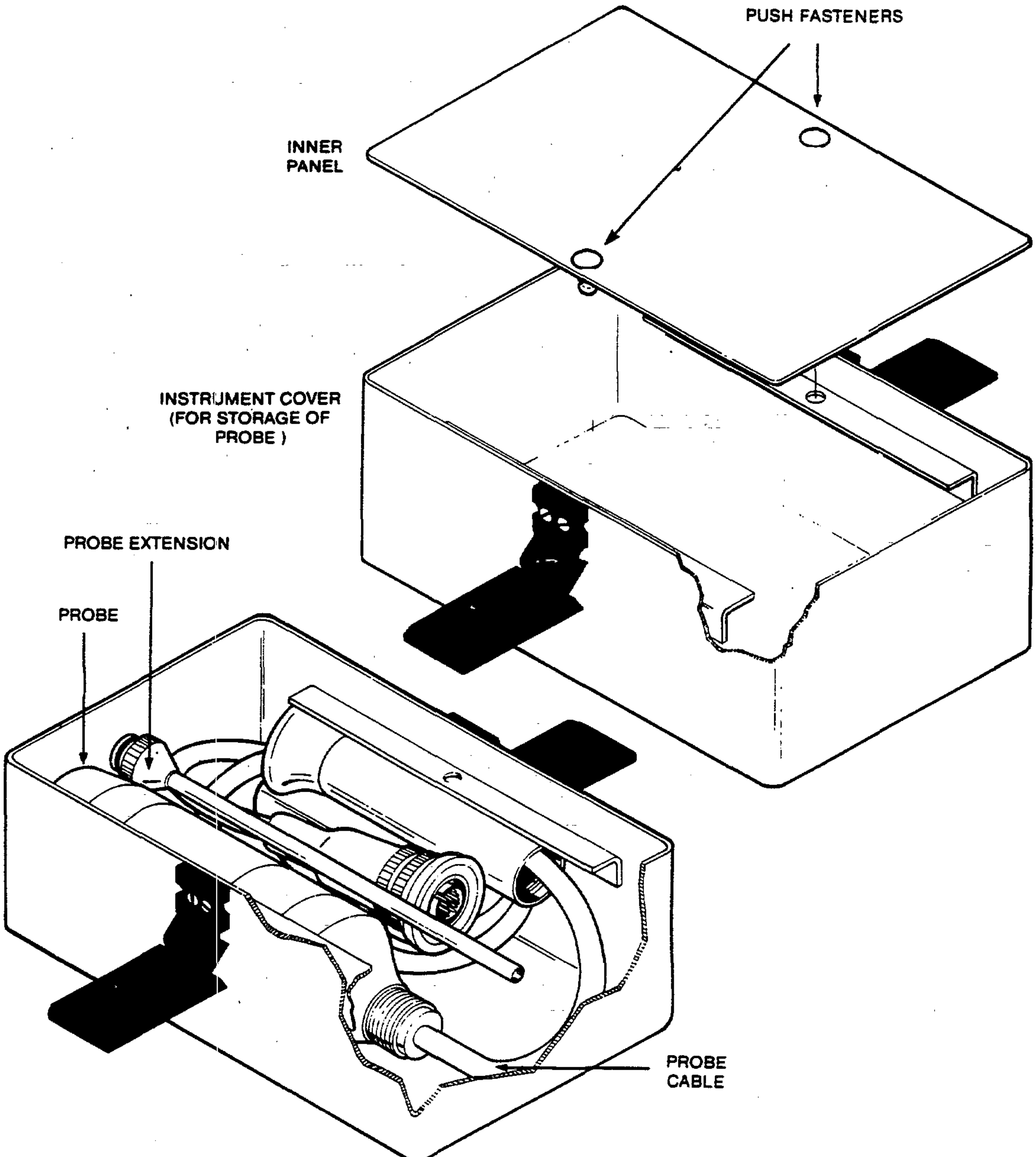

Repeated storage of probe in this manner is not recommended due to cable wear. Instrument cover may also be used for storing battery charger.

FIGURE 1-3
PROBE STORAGE
INSTRUMENT COVER

AR302065

TABLE 1-1

SPECIFICATION DATA

a. DESIGN FEATURES

Range settings	0 to 20, 200, 2000 ppm (other ranges available on request)
Lamp rating	10.2 eV standard, 9.5 or 11.7 eV optional
Audible alarm, low or high limit (optional)	85 db at 3'

b. CHARACTERISTICS (see NOTE)

Detection Range *	0.1 to 2000 ppm (parts per million by volume)
Minimum Detection Level *	0.1 ppm
Maximum Sensitivity *	0 to 20 ppm FSD at SPAN = 9.8 (full scale deflection) 0 to 2 ppm FSD at SPAN = 0.0
Repeatability *	+/- 1% of FSD
Linear Range *	0.1 to 400 ppm
Useful Range *	0.1 to 2000 ppm
Response Time	Less than 5 seconds to 90% of FSD
Ambient Humidity	up to 90% RH (relative humidity)
Operating Temperature, Ambient	-10 to 40 degrees C.
Operating Time on Battery, continuous use, without HNU recorder	Approximately 10 hours; at lower temperatures time is reduced due to effect of cold temperature on battery.
with HNU recorder (optional)	Approximately one half of normal time

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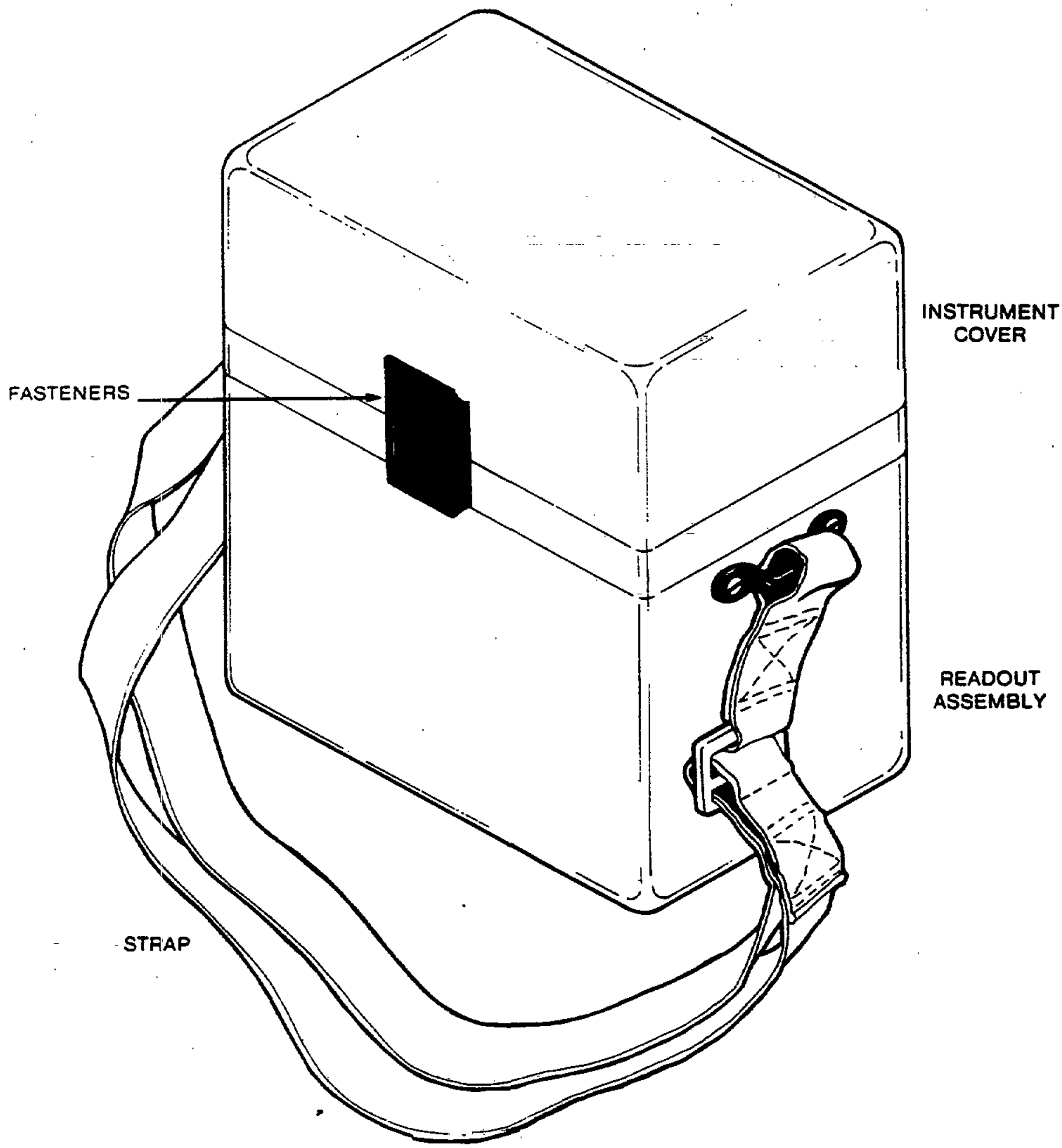

FIGURE 1-4
TRACE GAS ANALYZER
STORED CONDITION

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TABLE 1-1 cont.

Recharge time from full discharge	Full recharge - 12 to 14 hours
Recharge current	Max 0.4 amps at 15 V DC
Battery Charger Power	120 V AC, single phase, 50-60 cycle, 1.5 Amps

NOTE: * When equipped with 10.2 eV Probe with SPAN set at 9.8 and measuring benzene. Values will vary for other compounds and conditions.

TABLE 1-2

EQUIPMENT SIZE & WEIGHT

Quantity	Name	Overall dimensions cm (inches)	Weight, kg (lbs.)	Volume, cm3 (cu. ft.)
1	Trace Gas Analyzer (stored condition)	21W x 13D x 24H (8 1/4 x 5 3/16 x 9 1/2)	3.8 (8.2)	6552 (0.23)
	Probe Assembly	6.3 Diam x 28.5L (2 1/2 x 11 1/4)	0.55 (1.2)	564 (0.02)
	Readout Assembly	21W x 13D x 16.5H (8 1/4 x 5 3/16 x 6 1/2)	3.2 (7.0)	4504 (0.16)
1	Battery Charger with cord	10W x 12.7D x 9L (4 x 5 x 3 1/2)	0.4 (0.9)	1143 (0.04)

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SECTION 2

OPERATION

2.1 INTRODUCTION/UNPACKING

Unpack the instrument carefully. The carton will contain the housing, straps, battery charger, additional probes, regulator and cylinder if ordered, spare parts, supplies and a manual. Be sure all items are removed before discarding the carton.

Attached to the instrument is a warranty card which should be filled out completely and returned to HNU Systems.

2.2 CONTROLS AND INDICATORS

The controls and indicators are located on the front panel of the readout assembly (see Figure 2-1) and are listed and described in Tables 2-1 and 2-2.

2.3 OPERATING PROCEDURES

The following procedures are to be used in operating the analyzer:

a. Unclamp the cover from the main readout assembly.

b. Remove the inner lid from the cover by pulling out the two fasteners.

c. Remove the probe, handle and cable from the cover. Attach the handle to the front part of the probe.

d. Connect the probe cable plug to the 12 pin keyed socket on the readout assembly panel. Carefully match the alignment slot in the plug to the key in the connector. Screw down the probe connector until a distinct snap and lock is felt.

e. Screw the probe extension into the probe end cap. The probe may be used without the extension if desired.

f. Set the SPAN control for the probe being used (10.2, 9.5, or 11.7 eV) as specified by the initial factory calibration or by subsequent calibrations.

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(Red)

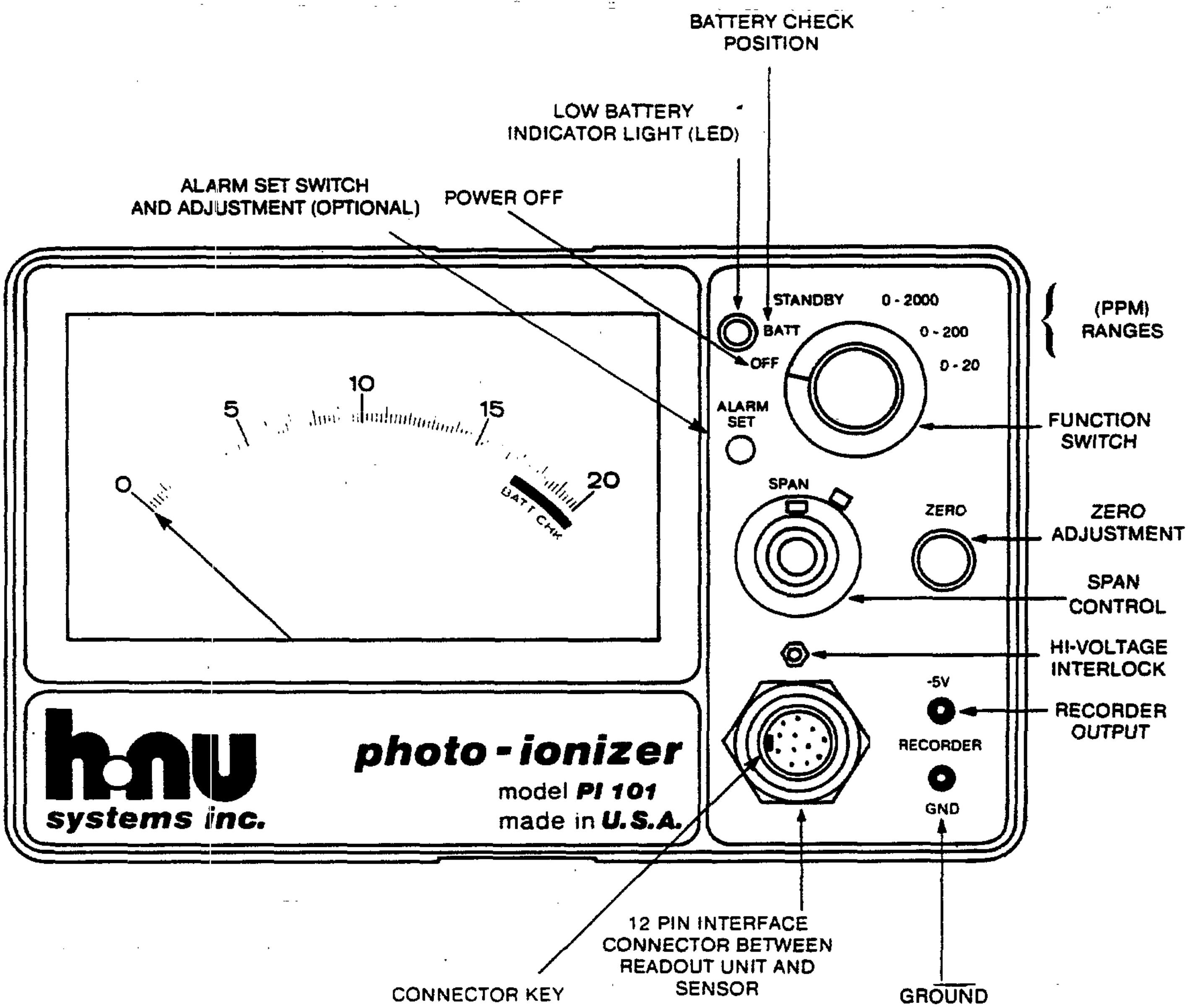

FIGURE 2-1
CONTROLS AND INDICATORS

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TABLE 2-1

CONTROLS

Name	Position	Function
Function Switch	---	Controls the operation of the analyzer
	OFF	All operations OFF
	BATT (battery check)	Checks the condition of the battery. If the meter needle is in the green arc, the battery is charged. If not the battery should be recharged. Charging can be done in any position, best in OFF; see directions on charger.
	STANDBY	All electronics ON, ultraviolet (UV) light source OFF. This position conserves power and extends battery life. This position is used to set the analyzer zero position. (i.e. no UV light, no signal)
	0-2000	Sets range of meter at 0-2000 ppm.
	0-200	Sets range of meter at 0-200 ppm.
	0-20	Sets range of meter at 0-20 ppm.
ZERO	---	With the function switch in STANDBY position, this potentiometer is used to adjust the reading to zero.

NOTE: See Figure 2-1 for locations.

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TABLE 2-1 cont.

SPAN	---	This vernier potentiometer is used to set the gain of the amplifier to give direct readings of the trace gas concentrations in ppm. The whole number of the setting appears in the window of the control, decimal appears on the dial. A lock secures it at a specific setting.
HI-VOLTAGE	---	This is a normally open microswitch.
	Open	Switch is open when cable not connected, disconnecting high voltage for the UV lamp from the 12 pin connector as a safety precaution.
	Closed	Switch is automatically closed when the cable is attached. This switch may also be closed manually during maintenance checks of the readout assembly without the probe cable attached.
ALARM SET (optional)	---	Potentiometer with screw-driver adjustment. Turns the audible alarm ON or OFF and sets the ppm level at which the alarm sounds. If alarm is low limit, it sounds when measured ppm falls below this value. If alarm is high limit it sounds when measured ppm exceeds this value.

NOTE: See Figure 2-1 for locations.

ORIGINAL (Red)

TABLE 2-2

INDICATORS AND DISPLAYS

Name	Function
Low Battery Indicator Light (red light) (see NOTE)	Illuminates when battery is discharged, indicates need for recharge. Do not use unit when this light is ON. Readings may be taken while battery is being recharged.
Meter (see NOTE)	Indicates concentration of measured gas.
Recorder (optional) (see Figures 2-1 And 8-3)	Provides a record of readings while analyzer operates unattended. Recorder inputs 0 to -5 V DC.

NOTE: See Figure 2-1 for locations.

ORIGINAL (Red)

g. Turn the function switch to the BATT (battery check) position. The needle on the meter will go to the green zone if the battery is fully charged. If the needle is below the green arc or if the Low Battery Indicator comes on, the battery must be recharged before the analyzer is used.

h. Set SPAN pot to the desired value based on the gas to be used.

i. Turn the function switch to the STANDBY position. Turn the zero adjustment until the meter needle is at zero.

j. Calibrate the instrument daily as described in Section 3. Calibration on the selected operating range is desirable.

k. If equipped with optional alarm, set or check the alarm setting at the level desired. Turn the function switch to the desired range, turn the zero adjustment control so the meter needle moves upscale thru the desired value. This simulates real conditions. Observe the reading when the alarm sounds. Adjust the ALARM SET, if required, with a screw driver. Turn the function switch to the STANDBY position and reset the zero position (para. h. above). If the range is to be changed, the alarm must be reset on that range.

l. To operate with optional recorder, add the recorder bracket (see Figure 8-3). Remove the plug in the analyzer case and insert power cord into the recorder. Then connect the signal leads to the appropriate jacks in the control module. The recorder is now operational.

NOTE: Ranges must be marked on the chart as the recorder prints the meter display as % of Full Scale.

m. Turn the function switch to the appropriate operating position. Start with the 0-2000 position and then switch to the more sensitive ranges. The UV light source should be on, confirmed by briefly looking into the probe to observe a purple glow from the lamp.

WARNING

Do not look at the light source closer than 6 inches with unprotected eyes. Observe only if necessary, then only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

ORIGINAL (Red)

n. The analyzer is now operational.

o. Hold the probe so that the extension is at the point where the measurement is to be made. The instrument measures the concentration by drawing the gas in at the end of the extension, through the ionization chamber, and out the handle end of the probe.

WARNING

The instrument measures gases in the vicinity of the operator and a high reading when measuring toxic or explosive gases should be cause for action for operator safety.

p. Take the reading or readings as desired taking into account that air currents or drafts in the vicinity of the probe tip may cause fluctuations in readings. Change the ranges as required.

q. Check battery condition as required. If the Low Battery Indicator comes on, turn analyzer off and recharge.

CAUTION

Use only in an emergency with a low battery when on battery charge.

ORIGINAL (Red)

r. After completion of use, check battery condition as described in para. g.

s. Turn function switch to OFF position.

t. When not operating, leave analyzer in assembled condition, and connected to battery charger.

u. When transporting, disassemble probe and extension from readout assembly and return equipment to its stored condition.

v. In case of emergency, turn function switch to OFF position.

2.4 BATTERY CHARGE

Check the battery charge as described in paragraph 2-3 g during each period of operation, at least once daily. If the battery is low as indicated by the meter reading or the warning indicator, it is necessary to recharge the battery.

To charge the battery, first insert the mini phone plug of the charger into the jack, J6, on the side of the bezel adjacent to the meter. Then insert the charger plug into a 120 or 230 V AC single phase, 50-60 cycle outlet. To ensure that the charger is functioning, turn the function switch, S1, to the battery check (BATT) position. The meter should deflect full scale if the charger is working and connections properly made. For normal battery charging, leave the function switch in the OFF position.

The analyzer can be operated, however, while recharging by turning the function switch to the desired position. Such usage will extend the time required to completely recharge the battery. The battery charger is not Div. II approved.

NOTE: On all Sira approved PI 101s it is necessary to connect the probe assembly before turning on the instrument and re-charging. Without following this procedure the instrument will not show battery check.

SECTION 3

CALIBRATION

3.1 INTRODUCTION

The PI 101 Analyzer is designed for trace gas analysis in ambient air and is calibrated at HNU with certified standards of benzene, vinyl chloride and isobutylene. Other optional calibrations are available (e.g., ammonia, ethylene oxide, H2S, etc.). Calibration data is given in the data sheet. If a special calibration has been done, the data is given in the Application Data Sheet, which notes the sample source, type of calibration (see Section 8, Appendix), and other pertinent information.

Good instrumentation practice calls for calibration on the species to be measured in the concentration range to be used. This procedure assures the operator that the analyzer is operating properly and will generate reliable data.

Some general points to consider when calibrating the PI 101 are that the analyzer is designed for operation at ambient conditions and therefore the gas standards used for calibration should be delivered to the analyzer at ambient temperatures and pressure and at the proper flow rates.

WARNING:

The PI 101 is a non-destructive analyzer; calibrations using toxic or hazardous gases must be done in a hood.

The frequency of calibration should be dictated by the usage of the analyzer and the toxicity of the species measured. If the analyzer has been serviced or repaired, calibration should be done to verify operation and performance. It is recommended that calibration be checked frequently at first (daily or every other day) and then regularly based on the confidence level developed.

The normal meter scaleplate is 0 to 20. If the scaleplate is different, refer to the Application Data Sheet. If there are questions, consult the HNU representative before proceeding with calibration check.

An accurate and reliable method of calibration check is to use an analyzed gas cylinder in a test setup as shown in Figure 3-1 and described below. Additional material on calibration is given in Section 8, Appendix.

3.2 ANALYZED GAS CYLINDER

a. Concentration - The calibration gas cylinder is to contain the species of interest made up in an air matrix at or near the concentration to be analyzed. If the component is unstable in air, another matrix is to be used. The final calibration mixture should be similar to the sample the PI 101 will analyze. If the expected concentration is not known then a concentration should be chosen that will cause a scale displacement of 50 to 80% on the X10 range. Calibration on X10 range will provide accurate values on the X1 range as well.

For use on the 0-2000 range, a two-standard calibration is preferred: one at 70 to 85% of the linear range and the other at 25 to 35% of the linear range. With the linear range of approximately 600 ppm for most compounds these points would lie between 420 to 510 ppm and 150 to 210 ppm, respectively.

b. Stability - The calibration gas must be stable within the cylinder during the period of use. If the calibration is required in the field, then use of a small cylinder is recommended. In addition, the choice of cylinder material in contact with the gas must be considered (steel, aluminum or teflon). If there are any questions, the operator should request stability and usage information from the gas supplier.

WARNING

Extreme care must be taken in the handling of gas cylinders. Contents are under high pressure. In some cases, the contents may be hazardous. Many gas suppliers will provide data sheets for the mixtures upon request.

c. Delivery - The cylinder containing the calibration mixture must be connected to a proper regulator.

WARNING

Never open the valve on a gas cylinder container without a regulator attached.

Leak test all tank/regulator connections as well as the main cylinder valve to prevent toxic or hazardous materials from leaking into the work area. Care must be taken that the materials of construction of the regulator will not interact with the calibration gas.

One method of sampling the calibration gas is illustrated in Figure 3-1. Connect the cylinder to one leg of the tee, a flow meter to the opposite leg, and the probe to the third leg. The flow meter does not require a valve. If there is a valve, it must be left wide open. the flowmeter is only to indicate excess flow. Adjust the flow from the regulator such that only a little excess flow is registered at the flowmeter.

ORIGINAL (Red)

This insures that the PI 101 sees the calibration gas at atmospheric pressure and ambient temperature.

d. Usage - Generally, a gas cylinder should not be used below 200-300 psi as pressure effects could cause concentration variations. The cylinder should not be used past the recommended age of the contents as indicated by the manufacturer. In case of difficulty, verify the contents and concentration of the gas cylinder.

e. Alternate means of calibration are possible. For more information, contact the HNU Service Department.

3.3 PROBE

a. Identify the probe by the lamp label. If a question exists, disassemble the probe and inspect the lamp. The energy of the lamp is etched into the glass envelope.

b. Connect the probe to the readout assembly, making sure the red interlock switch is depressed by the ring on the connector.

c. Set the SPAN pot to the proper value for the probe being calibrated. Refer to the calibration memo accompanying the probe.

d. Check the Ionization Potential (IP) of the calibration gas to be used. The IP of the calibration gas must be at or below the IP of the lamp.

e. Proceed with the calibration as described in Section 3.4. Check the calibration memo for specific data. If any questions develop, call the HNU representative.

f. NOTE: The 11.7eV lamp has a special cleaning compound. Do not use water or any other cleaning compound with the 11.7 eV lamp. Do not interchange ion chambers, amplifier boards or lamps between probes. (See Section 5.2).

3.4 PROCEDURE

a. Battery check - Turn the function switch to BATT. The needle should be in the green region. If not, recharge the battery.

ORIGINAL (Red)

b. Zero set - Turn the function switch to STANDBY. In this position the lamp is OFF and no signal is generated. Set the zero point with the ZERO set control. The zero can also be set with the function switch on the X1 position and using a "Hydrocarbon-free" air. In this case "negative" readings are possible if the analyzer measures a cleaner sample when in service.

c. 0-20 or 0-200 range - For calibrating on the 0-20 or 0-200 range only one gas standard is required. Turn the function switch to the range position and note the meter reading. Adjust the SPAN control setting as required to read the ppm concentration of the standard. Recheck the zero setting (step b.). If readjustment is needed, repeat step c. This gives a two-point calibration; zero and the gas standard point. Additional calibration points can be generated by dilution of the standard with zero air if desired (see Section 8).

d. 0-2000 range - For calibrating on the 0-2000 range, use of two standards is recommended as cited in Section 3.2a. First calibrate with the higher standard using the SPAN control for setting. Then calibrate with the lower standard using the ZERO adjustment. Repeat these several times to ensure that a good calibration is obtained. The analyzer will be appoximately linear to better than 600 ppm, (see Figure 3-2). If the analyzer is subsequently to be used on the 0-20 or 0-200 range, it must be recalibrated as described in steps b. and c. above.

e. Lamp cleaning - If the span setting resulting from calibration is 0.0 or if calibration cannot be achieved, then the lamp must be cleaned (see Section 5.2).

f. Lamp replacement - If the lamp output is too low or if the lamp has failed, it must be replaced (see Section 5.3).

3.5 CALIBRATION CHECKING

Rapid calibration checking in the field can be accomplished by use of a small disposable cylinder containing isobutylene. Immediately after a calibration has been completed, a reading is taken on a special isobutylene standard. This provides a reference concentration measurement for later checking in the field. This can be done at any time with a portable cylinder containing this same special standard, using this reference reading as a check, and making adjustments to the analyzer if necessary. In effect, this is an indirect method of calibration, one maintaining the calibration to give direct readings for the original gas mixture, but using the portable isobutylene cylinder. Details are given in Section 8.2 of the Appendix.

ORIGINAL (Red)

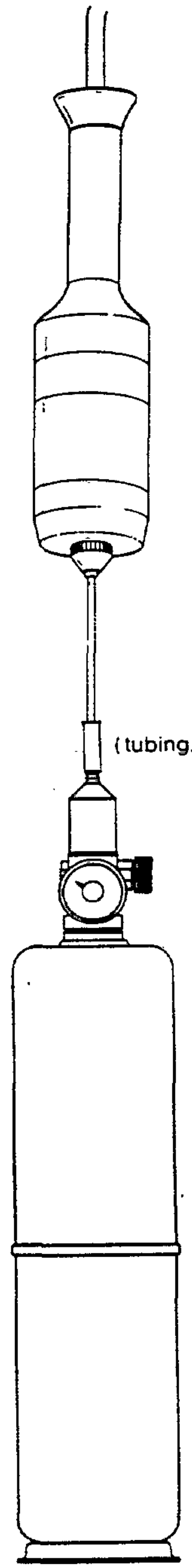
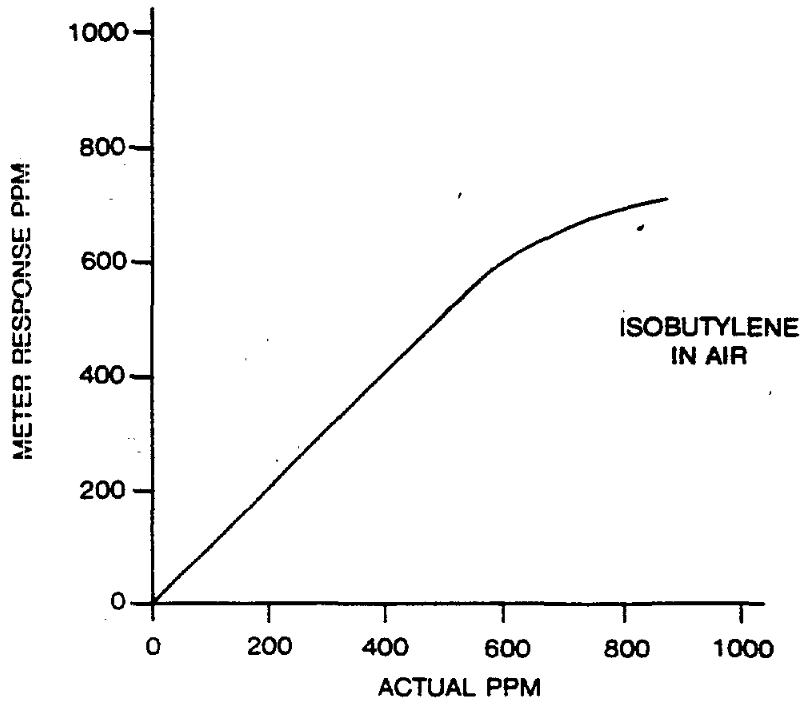


FIGURE 3-1
CALIBRATION TEST SET UP

AR302082

ORIGINAL (Red)



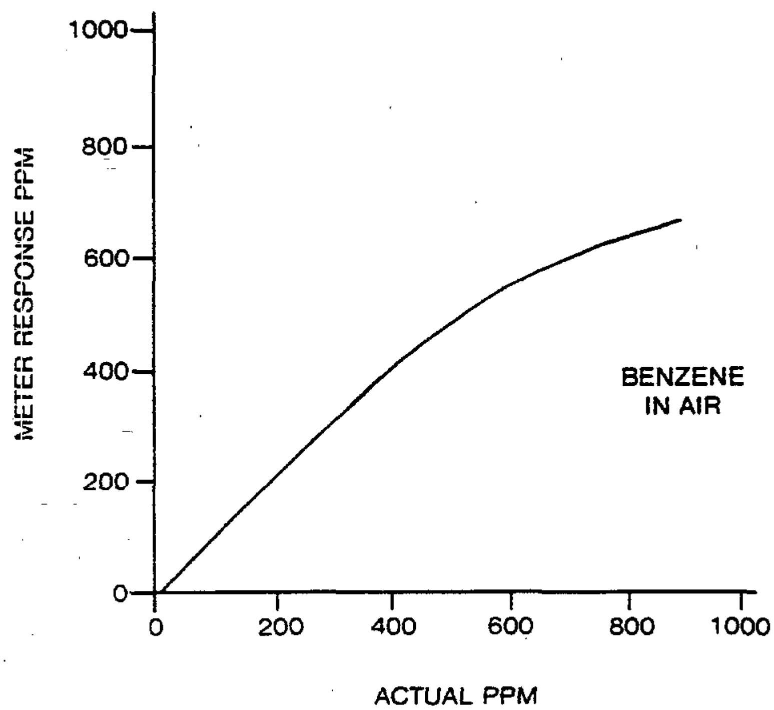


FIGURE 3-2
TYPICAL CALIBRATION CURVES (10.2 eV)

AR302083

SECTION 4

FUNCTIONAL DESCRIPTION

Original (Rev)

4.1 PRINCIPLE OF OPERATION

The analyzer measures the concentration of trace gases present in the atmosphere by photoionization. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and become a positive ion. This will occur when the ionization potential of the molecule in electron volts (eV) is less than the energy of the photon. The source of photons is an ultraviolet lamp with an energy of either 9.5, 10.2 or 11.7 eV.

The detection process is shown in Figure 4-1. Sample gases enter through the inlet into the ion chamber and are exposed to photons emanating from the ultraviolet lamp. Ionization occurs for those molecules having ionization potentials near to or less than that of the lamp.

A positive-biased polarizing electrode causes these positive ions to travel to a collector electrode in the chamber. Thus the ions create an electrical current which is amplified and displayed on the meter.

This is proportional to the concentration of trace gas present in the ion chamber and to the sensitivity of that gas to photoionization.

In service, the analyzer is first calibrated with a gas of known composition equal, close to or representative of that to be measured.

4.2 IONIZATION POTENTIALS

Gases with ionization potentials near to or less than that of the lamp will be ionized. These gases will thus be detected and measured by the analyzer.

Gases with ionization potentials higher than that of the lamp will not be detected.

Ionization potentials for various atoms, molecules and compounds are given in Tables 8-1 thru 8-13 in Section 8, Appendix.

The ionization potential of the major components of air, i.e., oxygen, nitrogen, and carbon dioxide, range from about 12.0 eV to about 15.6 eV and are not ionized by any of the three lamps.

Gases with ionization potentials near to or slightly higher than the lamp are partially ionized, with low sensitivity.

4.3 IONIZATION SENSITIVITY

The amount of ionization of a species of gas exposed to photons, its sensitivity, is a characteristic of that particular species. This is illustrated in Table 4-1 for a number of chemical groupings and in Table 8-14 for a large number of individual species when exposed to photons from a 10.2 eV lamp.

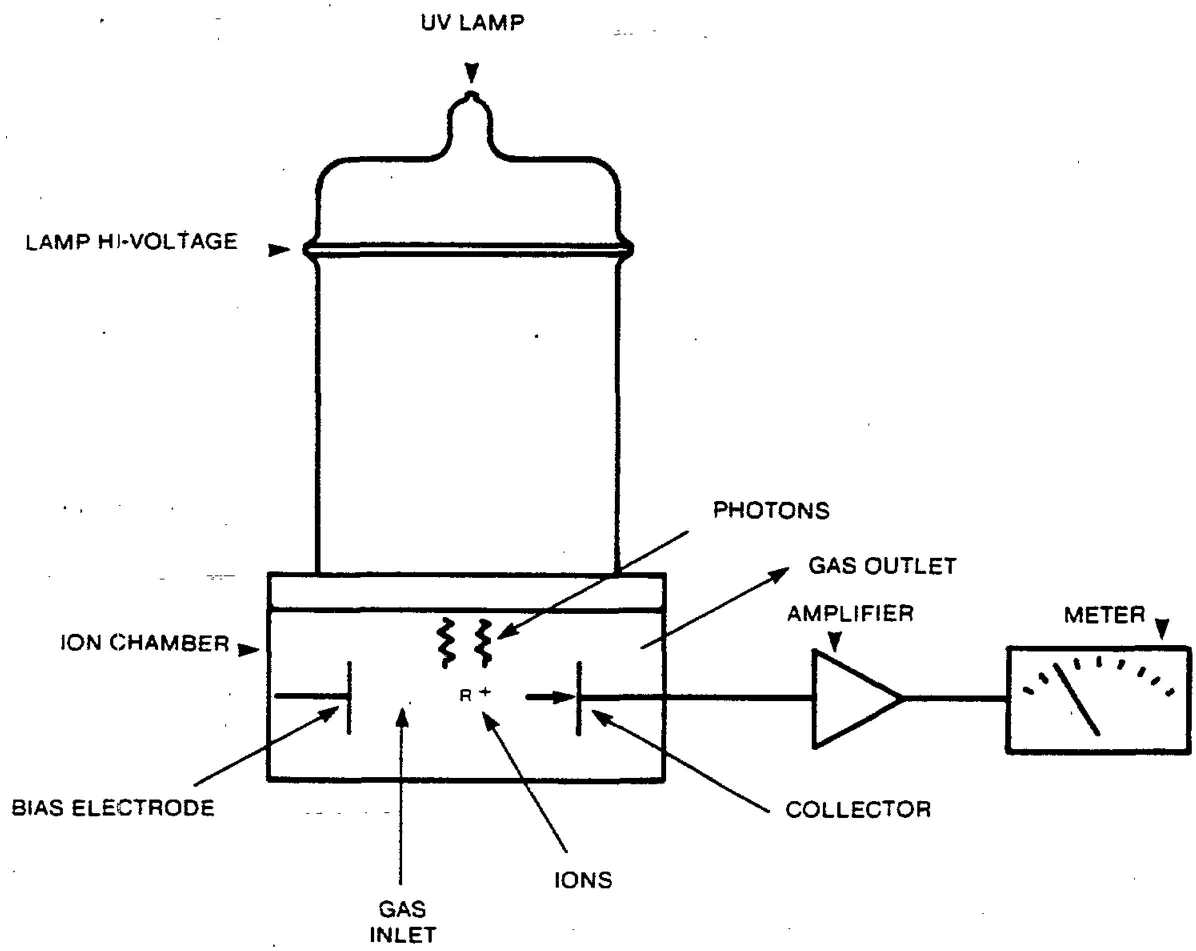


FIGURE 4-1
DETECTION PROCESS

AR302085

The species with the higher values are more sensitive to the 10.2 eV photons than are those with lower values. For example, referring to data in Table 8-14, an analyzer calibrated for benzene, when measuring a sample containing 10 ppm of benzene, will read 10.0 and when measuring a sample containing 10 ppm of vinyl chloride will read 5.0. This shows the lower sensitivity of the vinyl chloride. Similar conditions are the case for the 9.5 and 11.7 eV lamps.

4.4 CALIBRATED PROBES AND SELECTIVITY

The standard probe provided with the analyzer contains a 10.2 eV lamp. Optional probes containing lamps of 9.5 and 11.7 eV permit selective determination or exclusion of species.

The probe with the 9.5 eV lamp permits measurement of species having IP values lower than 9.5 eV in the presence of interfering species with IP values above 9.5 eV.

The probe with the 11.7 eV lamp permits measurement of species with IP values above 10.2 up to aproximately 11.7 eV.

The probes with different lamps are interchangeable in use within individual readout assemblies for different applications. The amplifier and ion chamber in the probe are selected for the specific eV lamp. Lamps of different eV ratings cannot be interchanged between probes. Examples of selective application of these probes is given in Table 4-2. Additional applications of the use of the probes are described in the sections that follow and illustrated in Figure 4-2. Further examples are given (without discussion) in Table 4-3. Re-zeroing is performed after each probe interchange.

4.5 10.2 eV PROBE

The 10.2 eV probe is the standard probe used with the Trace Gas Analyzer. The approximate span settings for a 10.2 eV probe that would give direct readings of the amounts of trace gas of a particular species in a sample is given in Table 8-14. for example, when the span control is set at 4.3 the analyzer will read 10 ppm when measuring a sample containing 10 ppm of vinyl chloride. These span settings will vary with the condition of the lamp. Application of the 10.2 eV probe is illustrated in examples "a", "b", and "c" in Figure 4-2. In each case the trace gas (or gases) is contained in a standard atmosphere.

Example "a" shows the use of the 10.2 eV probe to measure Vinyl Chloride (IP=9.995) by itself.

Example "b" shows the use of the 10.2 eV probe to measure Vinyl Chloride (IP=9.995) in the presence of a second gas, Acetylene (IP=11.4). The acetylene is not ionized and the probe gives a direct reading of the Vinyl Chloride above.

Example "c" shows the use of the 10.2 eV probe to measure Isoprene (IP=9.08) by itself. A 9.5 eV probe may also be used but is less sensitive. the 10.2 eV probe is recommended.

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ORIGINAL (Red)

TABLE 4-1

RELATIVE PHOTOIONIZATION SENSITIVITIES FOR GASES

Chemical Grouping	Relative Sensitivity (see NOTE)	Examples
Aromatic	10	Benzene, Toluene, Styrene
Aliphatic Amine	10	Diethylamine
Chlorinated Unsaturated	5-9	Vinyl Chloride, Vinylidene Chloride, Trichloroethylene
Carbonyl	7-9	MEK, MiBK, Acetone, Cyclohexanone
Unsaturated	3-5	Arolein, Propylene, Cyclohexanone, Allyl Alcohol
Sulfide	3-5	Hydrogen Sulfide, Methyl Mercaptan
Paraffin (C5-C7)	1-3	Pentane, Hexane, Heptane
Ammonia	0.3	
Paraffin (C1-C4)	0	Methane, Ethane

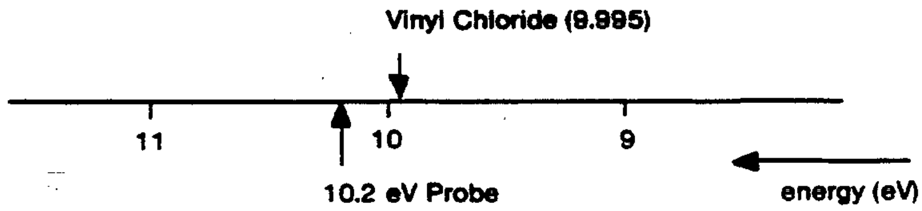
NOTE: Relative sensitivity = meter reading when measuring 10 ppm of the listed gas with instrument with 10.2 eV probe calibrated for 10 ppm of benzene, span pot setting = 9.8 for direct reading of benzene.

TABLE 4-2

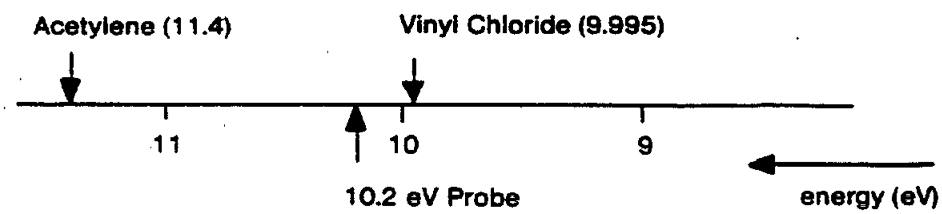
TYPICAL APPLICATIONS OF INTERCHANGEABLE PROBES

Compound	Ionization potentials (eV)	Relative Sensitivity 9.5/10.2 eV	Relative Sensitivity 11.7/10.2 eV
p-Xylene	8.44	0.10	0.104
p-Chlorotoluene	8.70	0.09	0.112
Toluene	8.82	0.09	0.112
o-Chlorotoluene	8.83	0.075	0.112
Ethyl Acetate	9.19	0.075	0.112
Benzene	9.24	0.10	0.10
Methyl Mercaptan	9.24	0.10	0.072
Pyridine	9.32	0.075	0.122
Allyl Alcohol	9.67	0.10	0.112
Crotonaldehyde	9.88	0.075	0.104
Amyl Alcohol	9.80	0.09	0.116
Cyclohexane	9.88	0.075	0.104
Vinyl Chloride	9.95	0.085	0.112
Butanol	10.94	0.09	0.176
Ammonia	10.15	0.06	0.160
Acetic Acid	10.37	0.04	0.560
Ethylene	10.52	0.0	0.320
Ethylene Oxide	10.56	0.0	0.298

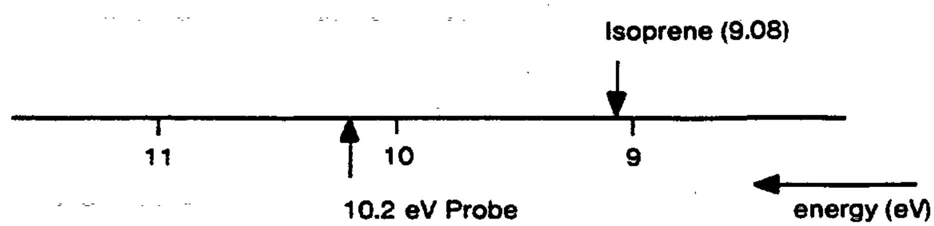
$$\text{Relative sensitivity} = \frac{\text{Response with 9.5 or 11.7 eV probe}}{\text{Response with 10.2 eV probe}}$$



a. 10.2 eV probe measures Vinyl Chloride (IP = 9.995)



b. 10.2 eV Probe measures Vinyl Chloride (IP = 9.995) but not Acetylene (IP = 11.4)



c. 10.2 eV Probe measures Isoprene (IP = 9.08)

FIGURE 4-2
APPLICATION OF PROBES

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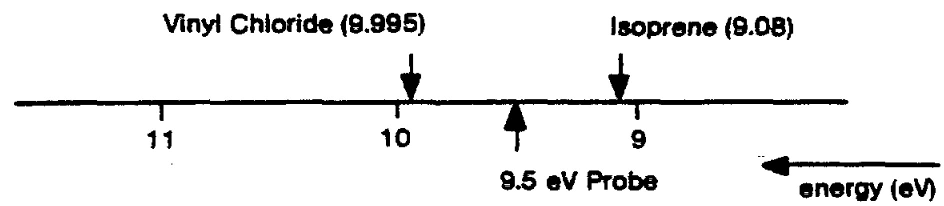
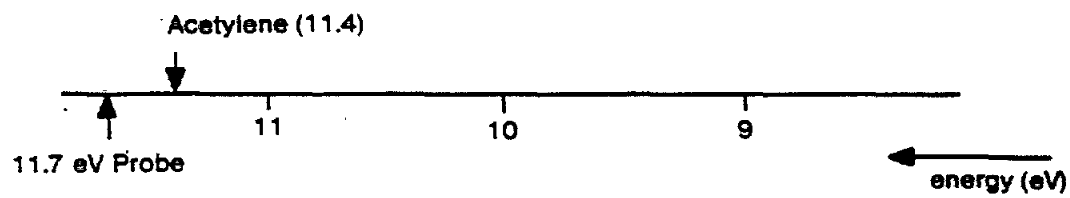
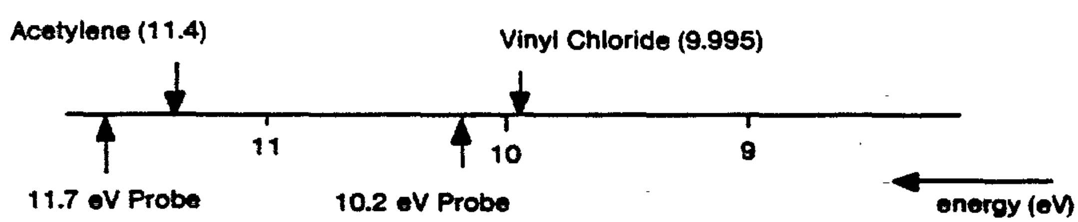


d. 9.5 eV Probe measures Isoprene (IP = 9.08) but not Vinyl Chloride (IP = 9.995)



e. 11.7 eV Probe measures Acctylene (IP = 11.4)



f. 11.7 eV Probe measures both Acetylene (IP = 11.4) and Vinyl Chloride (IP = 9.995)

10.2 eV Probe measures Vinyl Chloride but not Acetylene

Difference between the two readings is the measure of Acetylene

FIGURE 4-2
APPLICATION OF PROBES CONTINUED

AR302090

TABLE 4-3

PROBE APPLICATION EXAMPLES

Application	Recommended Probe
Styrene (IP = 8.47) Alone	10.2
Hexane (IP = 10.48) Alone	10.2
Formaldehyde (IP = 10.87) Alone	11.7
Styrene/Hexane Together	10.2 and 9.5 Use 10.2 to measure total, 9.5 to measure Styrene, difference will be the concentration of Hexane.
Formaldehyde/Styrene Together	10.2 and 11.7 Use 11.7 to measure total, 10.2 to measure Styrene, difference will be the contentration of Formaldehyde

.6 9.5 eV PROBE

The 9.5 eV probe is used to measure gases with IP<9.5 when it is necessary to exclude gases that may be present having IP>9.5 eV and <10.2 eV. This is illustrated by example "d" in Figure 4-2. Here a 9.5 eV probe is used to measure Isoprene (IP=9.08) in the presence of Vinyl Chloride (IP=9.995).

Gain settings for a 9.5 eV probe to give direct readings for various species are given in Table 8-15.

4.7 11.7 eV PROBE

The 11.7 eV Probe is used to measure trace gases with IP>10.2 eV but less than 11.7 eV. The use of this probe by itself is illustrated in example "e". Here the 11.7 eV probe is used to measure Acetylene (IP=11.4 eV). The use of this probe in conjunction with a 10.7 eV probe is illustrated in example "f". In this case, two gases are present, Acetylene (IP=11.4) and Vinyl Chloride (IP=9.995). The objective is to obtain a measurement of the Acetylene alone.

The 11.7 eV probe measures the total presence of both Acetylene and Vinyl Chloride together. The 10.2 eV probe measures just the Vinyl Chloride, excluding the Acetylene. The difference between the two readings is the measure of the Acetylene.

Gain settings for the 11.7 eV probe to give direct readings for various species are given in Table 8-15.

4.8 EQUIPMENT DESCRIPTION

The components of the analyzer are located in the probe and the readout assembly (see Figures 4-3 and 4-4). The ion chamber, UV light source, amplifier board, and fan are located in the probe assembly. The battery, the power supply board, and the meter are located in the readout assembly. The probe and the readout assembly are connected by an 800 cm (32") cable.

The fan draws gas in through the probe and ion chamber. The flow rate is approximately 100 cubic centimeters per minute. Small variations in the flow rate do not affect the measurement. A major obstruction to the flow, however, will prevent proper operation and lengthen response time. The fan cannot draw a sample from any distance or across a pressure drop.

The output from the ion chamber is amplified and read out on the meter.

Voltage for the light source, ion chamber, amplifier and fan is provided from a DC converter on the power supply board. The battery provides the source of power for the converter. The positive side of the battery is grounded.

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there

The input signal from the ion chamber enters at connector P1/J1 (see schematic Figure 4-5), goes to transistor Q1 and amplifier A1. The zero adjustment setting on the control panel enters thru pins 3 and C on P2/J2, thence to the transistor Q1.

Power for the amplifier enters on pins D and F respectively. Span control adjustment from the control panel enters at pin B, signal output at pin E, and ground connector at pin J.

The output signal from the amplifier goes thru pin E in the cable connector P3/J3 to pad 11 on the power supply board, to the resistor network R39 thru R49, including the adjustable pot R48. From there it goes to the meter through the function switch on the control panel.

Connections from the resistor network through the function switch serve to set the operating range of the meter. Input to the span control potentiometer comes from this same network through the function switch. The output of the span control pot provides feedback control to the amplifier through pin H on the cable, pin B on the amplifier board, and feedback resistor R5 to the amplifier input.

Power for the UV lamp, D1, is provided by rectifier networks containing CR4-9 operating from the red and white terminals of transformer T1. Voltage for the lamp (pad 22 on the power supply board or J3 pin D, Figure 4-6) will be as follows for the several different conditions that may exist.

Condition	Voltage, V DC
Probe connected, lamp operating properly	-350 to -450
Probe connected, lamp not operating properly	-1100 to -1200
Probe not connected, high voltage switch not depressed	0 to -300
Probe not connected, high voltage switch depressed manually	-1100 to -1200

Power for the ion chamber is provided by rectifier network CR2 and 3 operating from terminals 6 and 7 of T1 and voltage regulator Z1. Power for the amplifier is provided by rectifier networks CR13-16 operating from terminals 4,5 and 8 of T1. Power for the fan motor is provided by rectifier network CR18-21 operating from terminals 1, 2 and 3 of transformer T1. Conversion of the DC from the battery for input power to T1 is accomplished by Z2. Power for a recorder is available at connector J7.

D3 provides indication if the battery voltage falls below the prescribed level of 11.23 V DC. J6 provides for connection of the battery charger. The six bank switch, S1, is the function switch. Microswitch S2 disables the high voltage power to the cable connector when disconnected.

The alarm board (optional) is connected to the power supply board by the cable containing connector P6/J6. The amplifier output signal, pin 9 on P6/J6 (see schematic Figure 4-6), goes to one input of amplifier U1 (see schematic Figure 4-5).

The output from the alarm set control on the front panel, pin 4 on P6/J6, goes to the second input of U1. The output from U1 operates the audible alarm through Q3 or Q2. Only one of these is connected at the factory to give low alarm or high alarm, respectively, as requested by the user. The alarm will operate when the signal falls or rises above this threshold. Reference power for the alarm setting enters the board at pin 2 and power for the amplifier and transistors Q1 thru Q3 enters at pin 5. The battery charger provides 15.0 V DC for recharging.

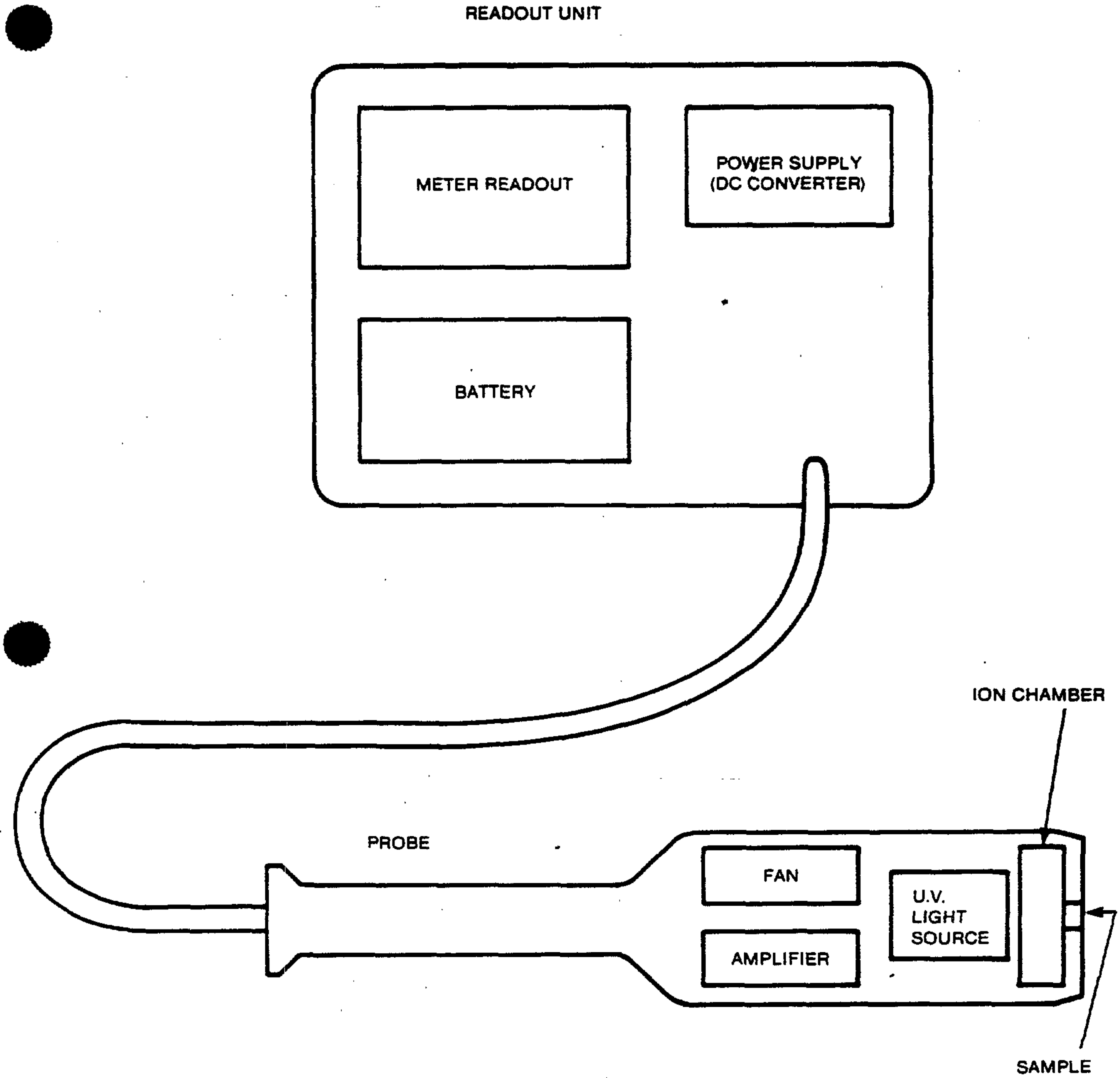
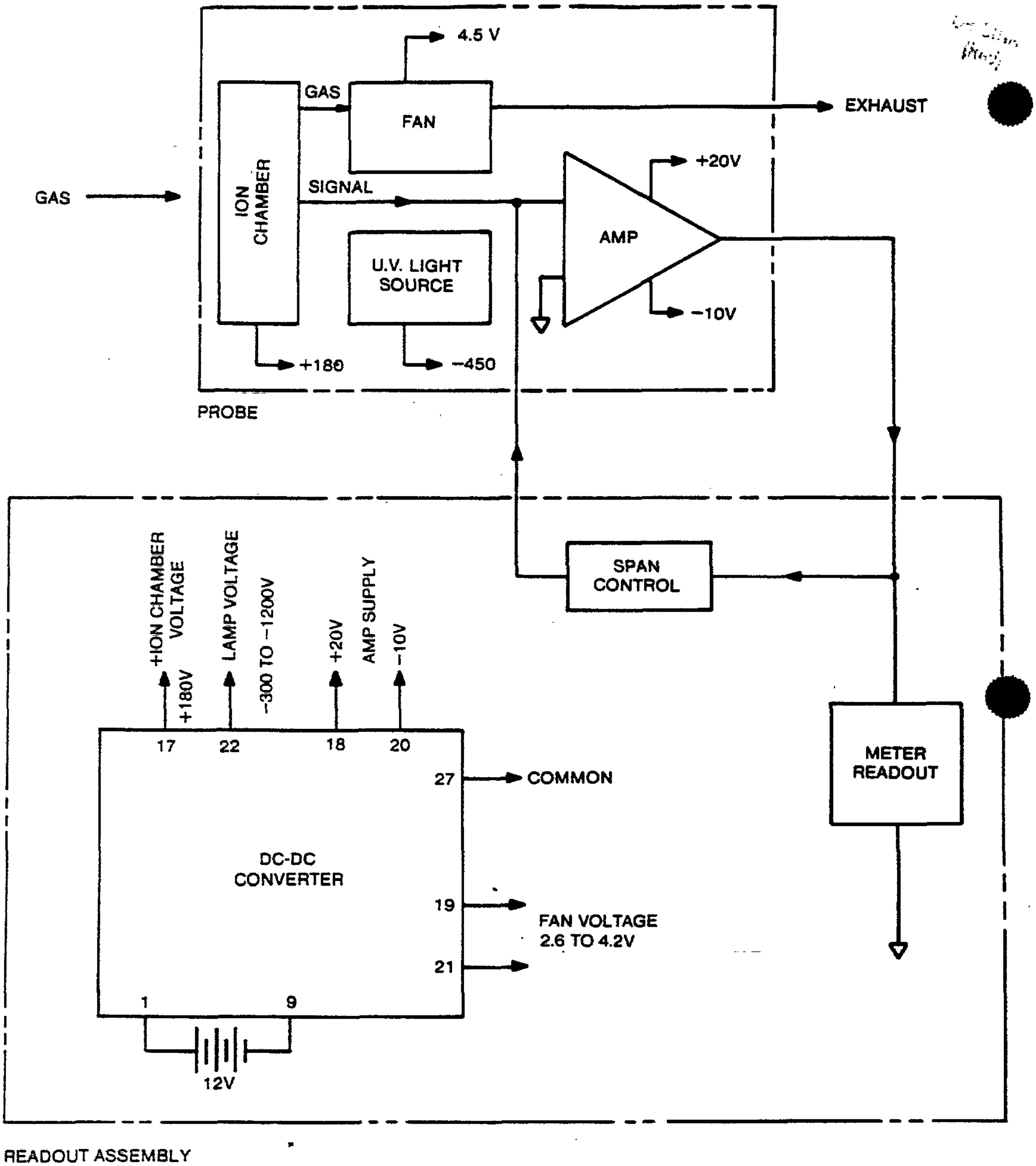


FIGURE 4-3
BLOCK DIAGRAM
COMPONENT LOCATION

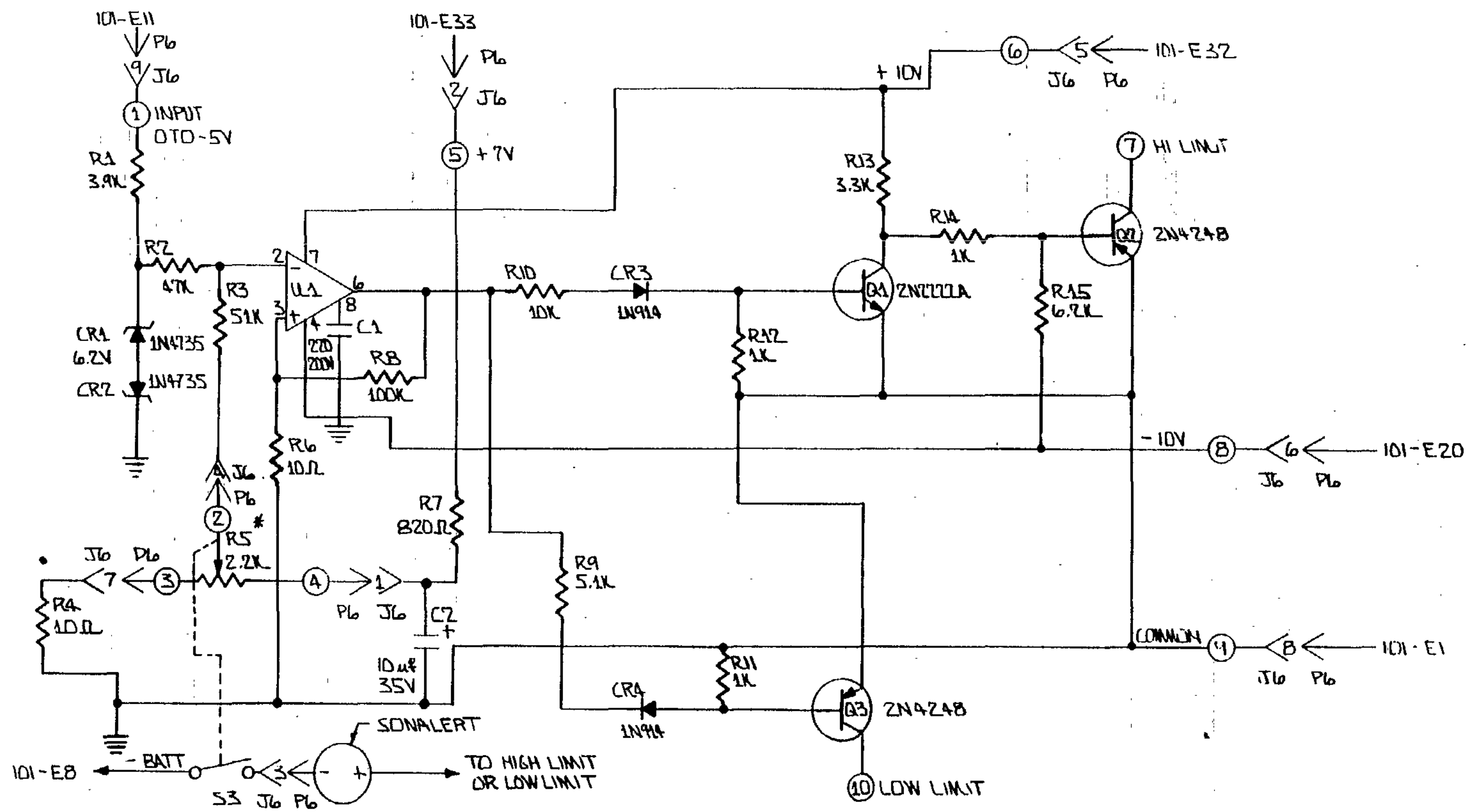
AR302095



NOTE: ALL VOLTAGES SHOWN ARE NOMINAL VALUES.

FIGURE 4-4
BLOCK DIAGRAM
ELECTRICAL CONNECTIONS

AR302096

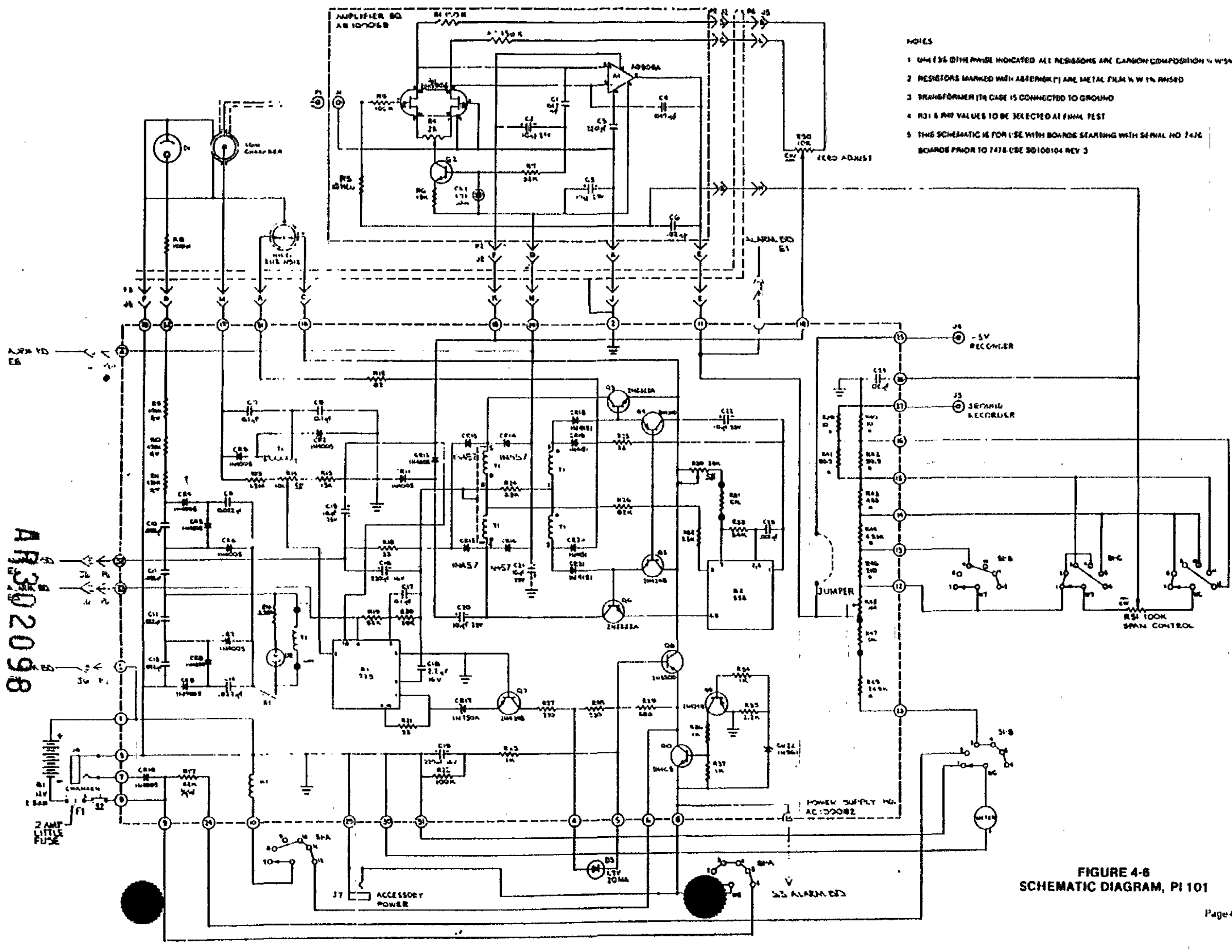


NOTE:

1) ALL RESISTORS ARE 1/4W C.C. OR C.F. ±5%.
2) FOR BOARDMASTER SEE HNU DWG. DB100584
3) FOR P. C. MASTER SEE HNU DWG. MB100583.
4) FOR SILKSCREEN SEE HNU DWG. MB100585.
5) * R5, S1 MOUNTED ON FRONT PANEL.

FIGURE 4-5
SCHEMATIC DIAGRAM, ALARM BOARD

AR302097



NOTES

1. UNLESS OTHERWISE INDICATED ALL RESISTORS ARE CARBON COMPOSITION ¼ W 5%
2. RESISTORS MARKED WITH ASTERISK (*) ARE METAL FILM ¼ W 1% RN55D
3. TRANSFORMER (T1) CASE IS CONNECTED TO GROUND
4. R31 & R47 VALUES TO BE SELECTED AT FINAL TEST
5. THIS SCHEMATIC IS FOR USE WITH BOARDS STARTING WITH SERIAL NO 7476 BOARDS PRIOR TO 7476 USE SD100104 REV 3

FIGURE 4-6
SCHEMATIC DIAGRAM, PI 101

ORIGINAL (Red)

SECTION 5

MAINTENANCE

5.1 INTRODUCTION

Maintenance of the analyzer consists of cleaning the lamp and ion chamber, replacement of the lamp or other component parts or subassemblies.

WARNING: Turn the function switch on the control panel to the OFF position before any disassembly. Otherwise, high voltage of 1200 V DC will be present.

WARNING: Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

WARNING: Do not look at the light source from any closer than 6 inches with unprotected eyes. Observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

CAUTION: Do not interchange lamps of different eV ratings in a probe. Amplifier and components are selected for a specific eV lamp. A probe with the wrong lamp will not operate properly.

5.2 UV LAMP AND ION CHAMBER CLEANING

During periods of operation of the analyzer, dust or other foreign matter could be drawn into the probe forming deposits on the surface of the UV lamp or in the ion chamber. This condition is indicated by meter readings that are low, erratic, unstable, non-repeatable, or drifting, or show apparent moisture sensitivity. These deposits interfere with the ionization process and cause erroneous readings. Check for this condition monthly or as required. Cleaning can be accomplished as follows:

a. Disassemble the probe and remove the lamp and ion chamber (see Section 5.5). Exercise great care in doing so to prevent inadvertent damage to these components.

b. First check the lamp window for fouling by looking at the surface at an incident angle. Any deposits, films or discoloration may interfere with the ionization process. Clean the window as follows:

1) 9.5 and 10.2 eV lamps

a) First clean by rubbing gently with lens tissue dipped in a detergent solution.

b) If this does not remove deposit, apply a small amount of HNU cleaning compound (PA101534) directly onto the lens of the lamp and spread evenly over surface with a non-abrasive tissue (e.g. Kim-Wipe) or a lens tissue.

c) Wipe off compound with a new tissue.

d) Rinse with warm water (about 80 degrees F) or damp tissue to remove all traces of grit or oils and any static charge that may have built up on the lens. Dry with new tissue.

e) Reinstall lamp in detector and check analyzer operation.

f) If performance is still not satisfactory replace the lamp. See Section 5.3 and Section 6.

2) 11.7 eV lamp

a) Clean by putting a freon or chlorinated organic solvent on a tissue and rubbing gently.

b) DO NOT CLEAN THIS LAMP WITH WATER OR ANY WATER MISCIBLE SOLVENTS (methanol or acetone). It will damage the lamp.

c) DO NOT USE THE CLEANING COMPOUND used for the 9.5 and 10.2 eV lamps under any circumstances on the 11.7 eV lamp.

c. Then inspect the ion chamber for dust or particulate deposits. If such matter is present, the chamber can be cleaned by removing the outer Teflon ring, and the four screws holding the retaining ring. Carefully move the retaining ring aside (NOTE: this is soldered) and remove the screen. A tissue or cotton swab, dry or wetted with methanol, can be used to clean off any stubborn deposits. The assembly can also be gently swirled in methanol and dried gently at 50-60 degrees C for approximately a half hour. No liquid must be present at reassembly as this would affect the performance. Do not clean the ion chamber with the HNU cleaning compound cited above in para. b.1)b).

d. Reassemble the probe and check analyzer operation.

e. If performance is still not satisfactory replace the lamp. See Section 5.3.

5.3 LAMP REPLACEMENT

To replace the lamp, disassemble the probe, remove the old lamp, install a new one of the same eV rating and reassemble.

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltage of 1200 V DC will be present.

CAUTION

Do not exchange lamps of different eV ratings in a probe. Amplifier and components are selected for a specific eV lamp. A probe with the wrong lamp will not operate properly.

Set the SPAN pot to 9.8 for the 10.2 eV lamp. Remove the readout assembly case (see Section 5.6). Locate the gain control potentiometer, R48, on the power supply board as shown on Figure 6-1. Recalibrate the analyzer adjusting this potentiometer, R48, with a small screwdriver to obtain the specified ppm reading, leaving the SPAN pot set at 9.8.

For the 9.5 and 11.7 eV lamps see the Application Data Sheet or calibrations memo for the proper span pot settings and readings.

WARNING

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

When calibration is accomplished, turn the analyzer OFF and replace the readout assembly in its case.

Adjustment of R48 potentiometer is used only when a new lamp is installed. At all other times adjustment is accomplished using the SPAN control potentiometer.

If calibration cannot be achieved, see Section 6, Troubleshooting.

ORIGINAL (Red)

5.4 LAMP SIZE CHANGE

If different applications for the analyzer would require different size lamps, separate probes, each with its own eV lamp, must be used. A single readout assembly will serve for any of the probes. A change in probe will require resetting of the zero control and the span pot. Calibration should be checked to verify proper operation.

5.5 PROBE DISASSEMBLY/ASSEMBLY

WARNING

Turn the function switch on the control panel to the off position before disassembly. Otherwise high voltage of 1200 V DC will be present.

ORIGINAL (Red)

Disconnect the probe cable connector at the readout assembly. Disassemble the probe by first removing the exhaust screw at the base of the probe adjacent to the handle (see Figure 5-1). Grasp the end cap in one hand and the probe shell in the other, gently pull to separate the end cap and the lamp housing from the shell.

Hold the lamp housing with the black end cap upright. Loosen the screws on the top of the end cap, separate the end cap and ion chamber from the lamp and lamp housing.

CAUTION

> Care must be taken so that the ion chamber does not fall out of the end cap or the light source does not fall out of the lamp housing.

Turn the end cap over in the hand. Tap lightly on the top. The ion chamber should fall out of the end cap into the hand.

Place one hand over the top of the lamp housing and tilt slightly. The light source will slide out of the housing.

The amplifier board can be removed from the lamp source housing assembly (see Figure 5-2) by unsnapping the coaxial connector, J1, and then removing the retaining screw. The amplifier board will then slide out of the housing assembly.

Reassemble the probe by first sliding the lamp back into the lamp housing. Place the ion chamber on top of the lamp housing, making sure that the contacts are properly aligned. The ion chamber fits only one way.

If the ion chamber is to be replaced always use one identical to the one being removed. Check the aperture (small: 3.0 mm; large: 6.0 mm) at the top of the ion chamber and materials of construction (gold-plated or Teflon) to ensure proper replacement. See Parts List, Section 7.

Place the end cap on top of the ion chamber and replace the two screws. Tighten the screws only enough to seal the O-ring.

ORIGINAL (Red)

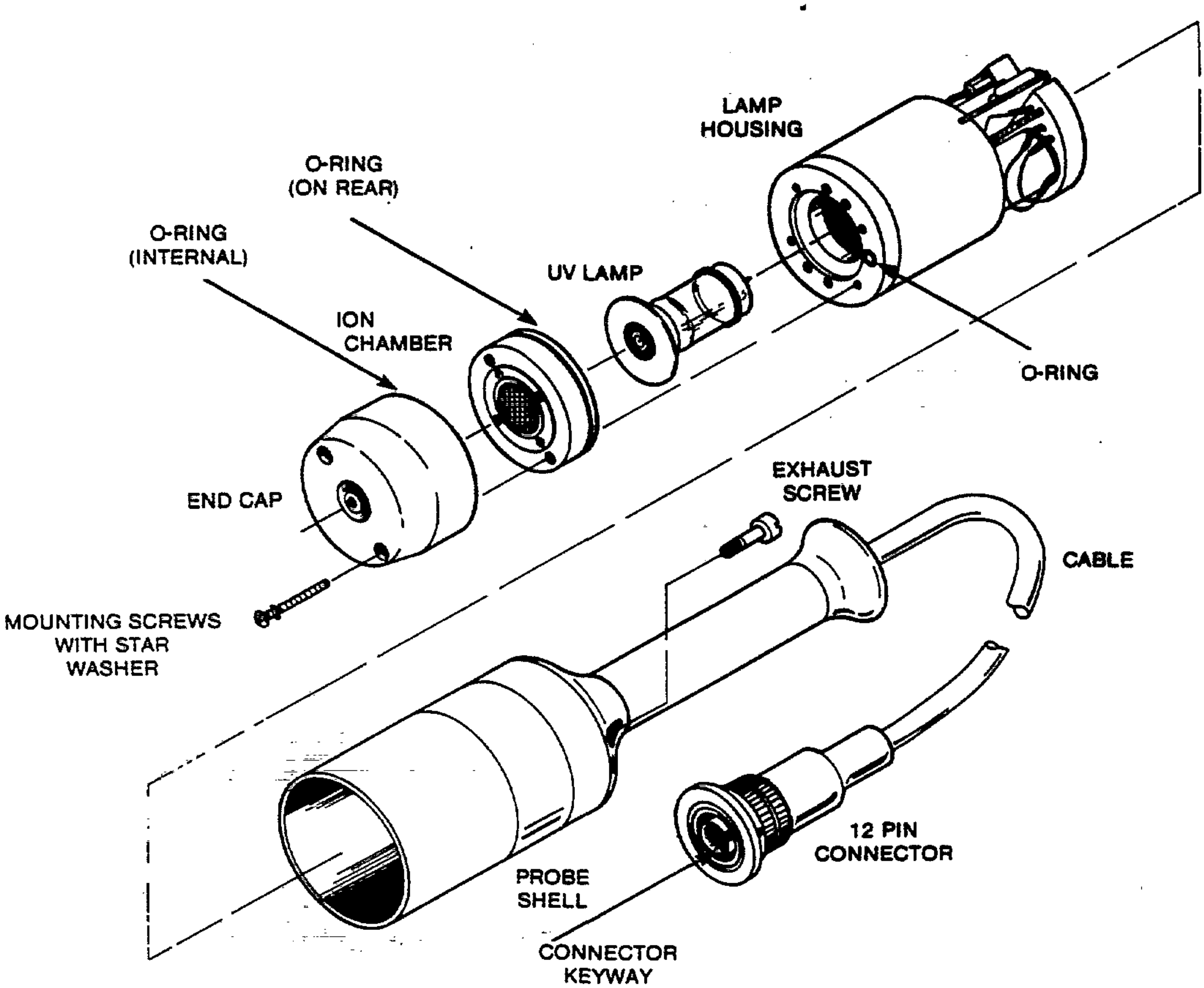


FIGURE 5-1
PROBE ASSEMBLY

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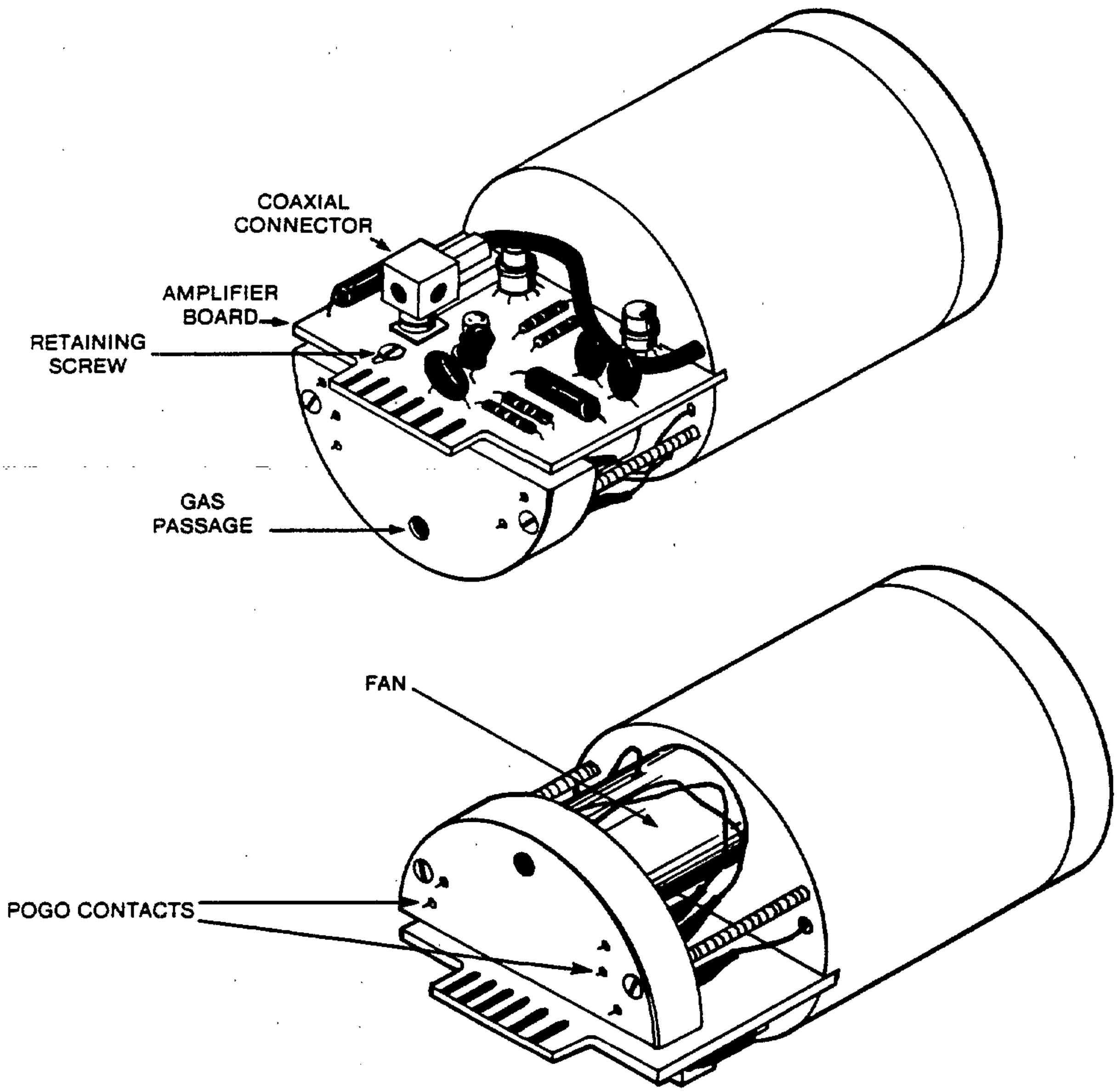

AR302105

FIGURE 5-2
LAMP HOUSING ASSEMBLY

ORIGINAL (Red)

CAUTION

Do not over-tighten these screws.

Line up the pins (pogo contacts) on the base of the lamp housing with the pins inside the probe shell. Gently slide the housing assembly into the probe shell.

The end cap should meet the probe shell evenly after final assembly. If not, the ion chamber may be installed wrong.

CAUTION

DO NOT FORCE the assembly into the shell.
It fits only one way.

If it does not reassemble readily, remove and check pin alignment. Check to ensure pogo contacts are not bent. Refasten the exhaust screw at the base of the probe.

Align the 12 pin probe connector to the readout assembly and reconnect with a twisting motion until a click occurs. Check to ensure the high voltage microswitch is properly depressed. The lamp should light if the function switch is turned to any position except STANDBY.

5.6 READOUT DISASSEMBLY/ASSEMBLY

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltage of 1200 V DC will be present.

Disconnect the probe cable connection. Remove recorder jacks and cable or the plastic plug cap. Loosen the screw on the botton of the case and, holding the instrument by the bezel, remove the case (see Figure 5-3).

a. The control assembly consisting of the Printed Circuit Board (PCB) and control panel can be separated from the readout assembly by the following steps:

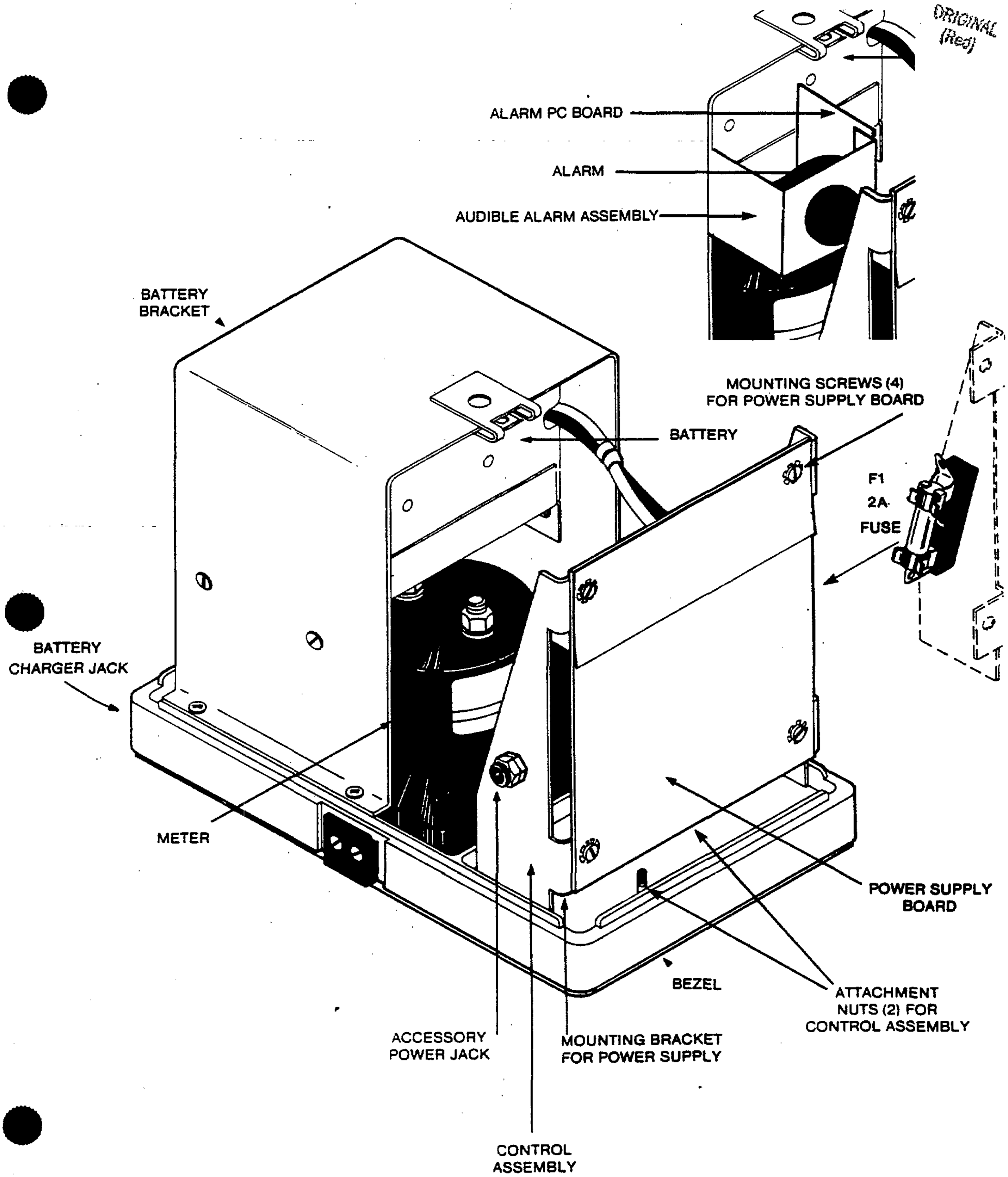

FIGURE 5-3
READOUT ASSEMBLY

AR302107

ORIGINAL (Red)

1) Separate the Molex connectors in the cables to the control assembly.

2) Remove the two attachment nuts at the base of the assembly.

3) Remove the two screws at the top of the power supply board holding it to the assembly brackets.

4) Compress the brackets and slide the assembly thru the bezel. Remove a third screw at the lower corner of the board, if necessary.

b. The optional alarm assembly can be separated as follows

1) Disconnect the cable (P6/J6 of Figure 4-5)

2) Remove the two screws holding the alarm assembly to the battery bracket

Reassembly is accomplished by reversing the above procedure.

NOTE: Be sure the function switch on the control panel is in the OFF position before inserting the control module into the case. If not, the fuse can be blown or damage can result.

ORIGINAL (Red)

SECTION 6

TROUBLESHOOTING

6.1 INTRODUCTION

The initial step of any troubleshooting is a thorough visual inspection to look for possible loose or open connections, shorts, dust or other obvious conditions.

Detailed troubleshooting for fault location and correction is accomplished by steps outlined in the following:

Troubleshooting Data	Table 6-1
Pad Data, Power Supply PCB	Table 6-2
Pad Location, Power Supply PCB	Figure 6-1
Pin Data, Amplifier PCB, P2/J2	Table 6-3
Pin Data, Probe Cable, P3/J3	Table 6-4
Pin Data, Alarm Cable, P6/J6	Table 6-5

Disassembly and reassembly as may be required for checking the equipment or replacing parts are described in Chapter 6.

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise high voltage of 1200 V DC will be present.

WARNING

Do not observe the light source closer than 6 inches with unprotected eyes. When necessary, observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

WARNING

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

If, after following the steps cited in this section, the analyzer is not functioning properly, contact the HNU Service Dept. for assistance. (Phone: (617) 964-6690).

TABLE 6-1

TROUBLESHOOTING DATA

ORIGINAL (Red)

Symptom	Probable Cause	Corrective Action
1. Meter indicates low battery	a. Blown fuse (Fuse F1, 2A, 5-3)	1) Check fuse. If blown, check for evidence of shorts in wiring, then replace fuse.
	b. Bad connections	1) Check wiring connections. Resolder poor or bad connections.
	c. Broken meter movement	1) Tip instrument rapidly from side to side. Meter needle should move freely, and return to zero. If faulty, replace with new meter.
	d. Battery dead	1) Disconnect battery and check with volt-ohmmeter. Replace if dead.
	e. Battery charge low	1) Recharge battery, check meter with function switch in BATT position to ensure the charger is operating properly (see Table 2-1, BATT)
2. Low battery	a. Power supply defective	1) Check power supply voltages (see Table 6-2 and Figure 6-1). If in error, replace power supply assembly.
3. UV lamp not ON	a. High Voltage interlock (Micro-switch S2) at probe cable connector on readout assembly not operating	1) Check by applying pressure to switch plunger with cable in place. Adjust the screw on side of cable connector, if required, to increase throw of switch plunger.
	b. High voltage supply out or faulty	1) Check high voltage output on power supply board (pad 22). If voltage not correct, (see Table 6-2) replace power supply board.

ORIGINAL (Red)

	c. Lamp not making proper connection with high voltage contacts.	1) Remove lamp, clean and tighten contacts, reinstall lamp.
	d. Lamp faulty	1) Replace lamp.
	e. Short in high voltage lines	1) Check wiring from power supply board to probe cable connector (J3 pin D) to UV lamp contacts (D1). Remove any shorts.
4. Fan not running	a. Fan stuck	1) Disassemble probe and clean passages and fan by blowing out dust. To remove larger particles use cotton swab, Q-tip or equal. Use care to not damage impellor rotor or blades. For disassembly see Section 5.5.
	b. Fan connections faulty	1) Check for wiring connections at fan motor and at probe cable connector (J3 pins A and C). Repair as required.
	c. Low or dead battery	1) Check battery output (power supply board, pad 9). Recharge or replace battery as required.
	d. Fan voltage not correct	1) Check fan voltage (power supply board pads 19 and 21, probe cable pins A and C). If not correct, replace power supply board.
		2) If fan voltages correct replace fan.
5. Meter does not respond	a. Dirty or open probe connection	1) Clean and tighten or resolder connections in probe.
	b. Broken meter	1) See 1-c-1 above.
	c. Dirty or open connections to meter	1) Clean and tighten connections at meter.
	d. Low or dead battery	1) See 4-c-1 above.
	e. Blown fuse	1) See 1-a-1 above.

ORIGINAL (Red)

6. Meter does not return to zero in STANDBY	a. Broken meter movement	1) See 1-c-1 above.
	b. Dirty or open connections to meter	1) See 5-c-1 above.
	c. Dirty or open connections in probe	1) See 5-a-1 above.
	d. Zero adjust faulty	1) Rotate zero adjust pot (see Fig. 2-1) (R50, Fig. 4.6). Check pot output at meter probe connector (J3 pins B and L). If voltage does not vary, replace zero adjust pot.
	e. Amplifier faulty	1) Rotate zero adjust pot. Check amplifier output at probe connector (J3 pin H) or observe meter. If voltage level on meter does not respond, replace amplifier board
	f. Ion chamber shorted	1) Clean ion chamber. (see Section 5.2). Reche[illegible] for return to zero in STANDBY.
		2) Replace ion chamber.
7. Meter readings, high or low	a. Incorrect calibration	1) Recalibrate (see Section 3).
	b. Lamp dirty	1) Clean lamp (see Section 5.2)
	c. Contamination in ion chamber.	1) Clean ion chamber. (see Section 5.2)
	d. Power supply board faulty	1) Check power supply board outputs (pads 17, 20 and 22 (Table 6-2). If voltages not correct, replace power supply board.
	e. Dirty or loose connections	1) Clean or tighten connections at amplifier board, probe cable, and meter.

ORIGINAL (Red)

8. Meter erratic, unstable or non-repeatable	a. Loose cable connection	1) Check cable connection at control panel. Observe meter. Tighten cable as required.
	b. Dirty or loose meter connections	1) Check meter connections. Clean and tighten as required.
	c. Contamination in ion chamber	1) Clean ion chamber. (see Section 5.2).
	d. Power supply board faulty	1) See 7-d-1 above.
	e. Unstable or noisy lamp	1) Observe lamp. (Important-see WARNING in Section 6.1). If operation not steady, replace lamp.
	f. Function switch in high gain, most sensitive position	1) Unstable meter operation is common with function switch in most sensitive position. Turn switch to less sensitive position if desirable.
	g. Fan not operating properly	1) Replace fan.
	h. Gas flow slow or stopped	1) See 4-a-1 above.
	i. Meter contacts dirty or loose	1) Clean and tighten contacts.
9. Drifting meter or apparent moisture sensitivity	a. Ion chamber contaminated	1) Clean ion chamber, (see Section 5.2).

ORIGINAL
(Red)

TABLE 6-2

PAD DATA, POWER SUPPLY PCB

Pad No.	Signal Name	Voltage (V DC)
1	Battery positive (+)	0
2	Ground	0
3	Battery charger (+)	0
4	Low Battery Indicator	
5	Low Battery Indicator	
6	Hi-Volt Relay Disconnect	-12
7	Battery Charger (-)	-11 to -15
8	Battery Negative (-)	-11 to -15
9	Battery Negative (-)	-11 to -15
10	Hi-volt Relay Disconnect	0 or -12
11	Amplifier Signal	0 to -5
12	Signal divider for span control	"
13	" " " " "	"
14	" " " " "	"
15	" " " " "	"
16	" " " " "	"
17	Ion Chamber accelerating voltage	+180
18	Zero adjust voltage power	+18 to +21
19	Fan Motor	-10.6 V nominal (see NOTE 2)
20	Amplifier Power	-9.5 to -10.5
1	Fan Motor	-14.5 nominal (see Section 4.8)
22	UV Lamp	up to -1200 (see Section 4.8)
23	Output Signal to Meter	0 to -5
24	Battery Check Voltage	-11 to -15
25	Not Used	---
26	Signal Feedback	0 to -5
27	Ground	0
28	Ground	0
29	Not Used	---
30	Ground	0
31	Ground	0
32	Alarm set power	+10
33	Alarm set power	+7

NOTES: 1. For Pad location, see Figure 6-1.

2. Differential potential for fan motor between pads 19 and 21 will be between 2.6 and 3.6 V DC.

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(Red)

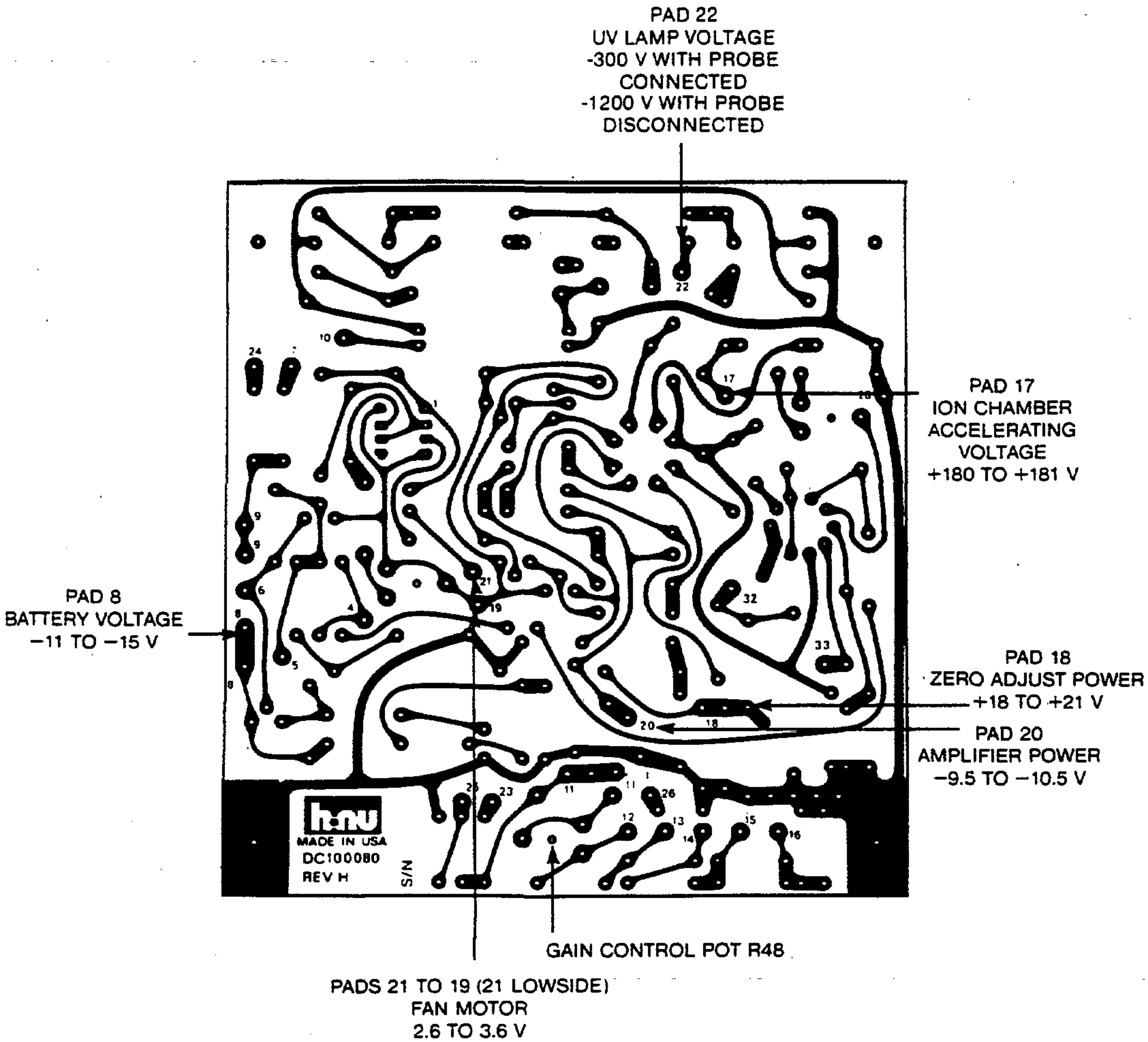

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FIGURE 6–1
PAD LOCATION, POWER SUPPLY PCB

ORIGINAL (Red)

TABLE 6-3

PIN DATA, AMPLIFIER PCB, P2/J2

Pin #	Signal Name	Voltage (V DC)
A	Ground	0
B	Span Control Setting	varying
C	Zero Adjust	varying
D	Amplifier Power	-9.5 to -10.5
E	Amplifier Signal	0 to -5.0
F	Zero Adjust Voltage	+18 to +21
3	Zero Adjust Voltage	varying

ORIGINAL (Red)

TABLE 6-4

PIN DATA, PROBE CABLE, P3/J3

Pin #	Signal Name	Voltage (V DC)
A	Fan Motor	-14.5 nominal (see NOTE)
B	Zero Adjust	varying
C	Fan Motor	-10.6 nominal (see NOTE)
D	UV Lamp	up to -1200 (see Section 4.8)
E	Amplifier Signal	0 to -5.0
F	Ground	0
H	Span Control Setting	varying
J	Ground	0
K	Zero adjust Voltage	+18 to +21
[illegible]	Zero Adjust	varying
M	Ion Chamber accelerating voltage	+180
N	Amplifier Power	-9.5 to -10.5

NOTE: Differential potential for fan motor between pads 19 and 21 will be between 2.6 and 3.6 V DC.

ORIGINAL (Red)

TABLE 6-5

PIN DATA, ALARM CABLE P6/J6

Pin #	Signal Name	Voltage (V DC)
1	Alarm set pot, high end	+5.1
2	Alarm set power	+7
3	Alarm power	0 or -11 to -15
4	Alarm set	+0.02 to +5.1
5	Alarm board power	+10
6	Amplifier power	-9.5 to -10.5
7	Alarm set pot, low end	+0.023
8	Ground	0
9	Amplifier signal	0 to -5.0

ORIGINAL (Red)

SECTION 7

PARTS LISTS

7.1 INTRODUCTION

This section lists and shows the location of all parts of the Photoionization Analyzer subject to repair and replacement. When ordering parts, specify model and serial numbers as well as part number. Return all defective warranty parts to HNU Systems Inc. Obtain a Return Materials Authorization Number (RMA#) from Service Department.

TABLE 7-1

ORIGINAL (Red)

REPLACEMENT PARTS LIST

MODEL PI-101
(See Fig. 7-1)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Part No.	Refer to Fig. No.	Assembly
	1	Probe Handle
79-AC100004	2	Probe Shell Assembly
54-DA100049	3	Exhaust Screw
79-AC100107	4	Fan/Light Source Assembly
80-101-095	5	95 eV Replacement Lamp
80-101-102		10.2 eV Replacement Lamp
80-101-117		11.7 eV Replacement Lamp
80-101-111		10.2 eV Selected Lamp (Specify Appl.)
79-AB10008	6	fan exhaust assembly
79-AB100069	7	amplifier board
79-AC100005A1	8	ion chamber assembly, sm. aperture (3.0 mm)
79-AC100005A2		ion chamber assembly, sm. aperture gold
79-AC100005A3		ion chamber assembly, lg. aperture (6.0 mm)
79-AC100005A4		ion chamber assembly, lg. aperture gold
54-DA100053	9	End cap for probe
	10	End cap screw
79-AA10011	11	Probe extension
79-PA 10010	12, 13, 14, 15	"O" ring kit
13-67-06J-14-11P	16	12 pin connector
79-AB100187A1	17	Probe cable w/connector ($5/ft. over 3')

ORIGINAL (Red)

REPLACEMENT PARTS LIST

MODEL PI-101
(See Fig. 7-2)
1 2 3 4 5 6 7 8 9 10 11

Part No.	Refer to Fig. No.	Assembly
25-680-402	1	Front Meter Glass
	2	
45-DA101316	3	Pot (span)
45-DA100029	4	Pot (zero)
79-AC100082	5	Power Supply Board
18-MDL-2	6	fuses, box of 12
79-AA100011	7	Battery
	8	
	9	
	10	
10-39-12	11	Grayhill switch

ORIGINAL (Red)

REPLACEMENT PARTS LIST

MODEL PI101
(see Fig. 7-3)
1 2 3 4 5

Part No.	Refer to Fig. No.	Assembly
DB100017-1	1	Strap, neck
DB100018-1	2	Strap, waist
AC100013-A1	3	Charger, battery: 15.0 VDC, 120 V AC, 1 pH input
DC100044-1	4	Case, cover
DB100050	5	Case, readout assembly

TABLE 7-4

ORIGINAL (Red)

PARTS LIST
ACCESSORIES
(No figure is provided for this list.)

Part No.	Description
101-300	Portable Recorder Has a 2" chart width with 2"/hour chart speed. Operates on 12 v DC power from analyzer. Complete with multiconductor interface cable for battery power and signal and mounting bracket for attaching recorder to side of analyzer.
101-301	Chart Paper For portable recorder, 6 rolls.
AB100378	Multiconductor Interface Cable For recorder, contains leads for connecting recorder to analyzer.)Included in part 101-300 above)
101-350	Calibration Gas Cylinder Contains 23 liters of span gas in air (300 psi) sufficient for 40-50 calibrations. (4" diameter by 12" high).
101-351	Regulator For use with calibration cylinder, Model 101-350, complete with gauges for reading both cylinder pressure and flow.
101-500	Cleaning Compound For removing deposits from window of 9.5 or 10.2 eV lamp (not the 11.7 eV lamp.)

ORIGINAL
(Red)

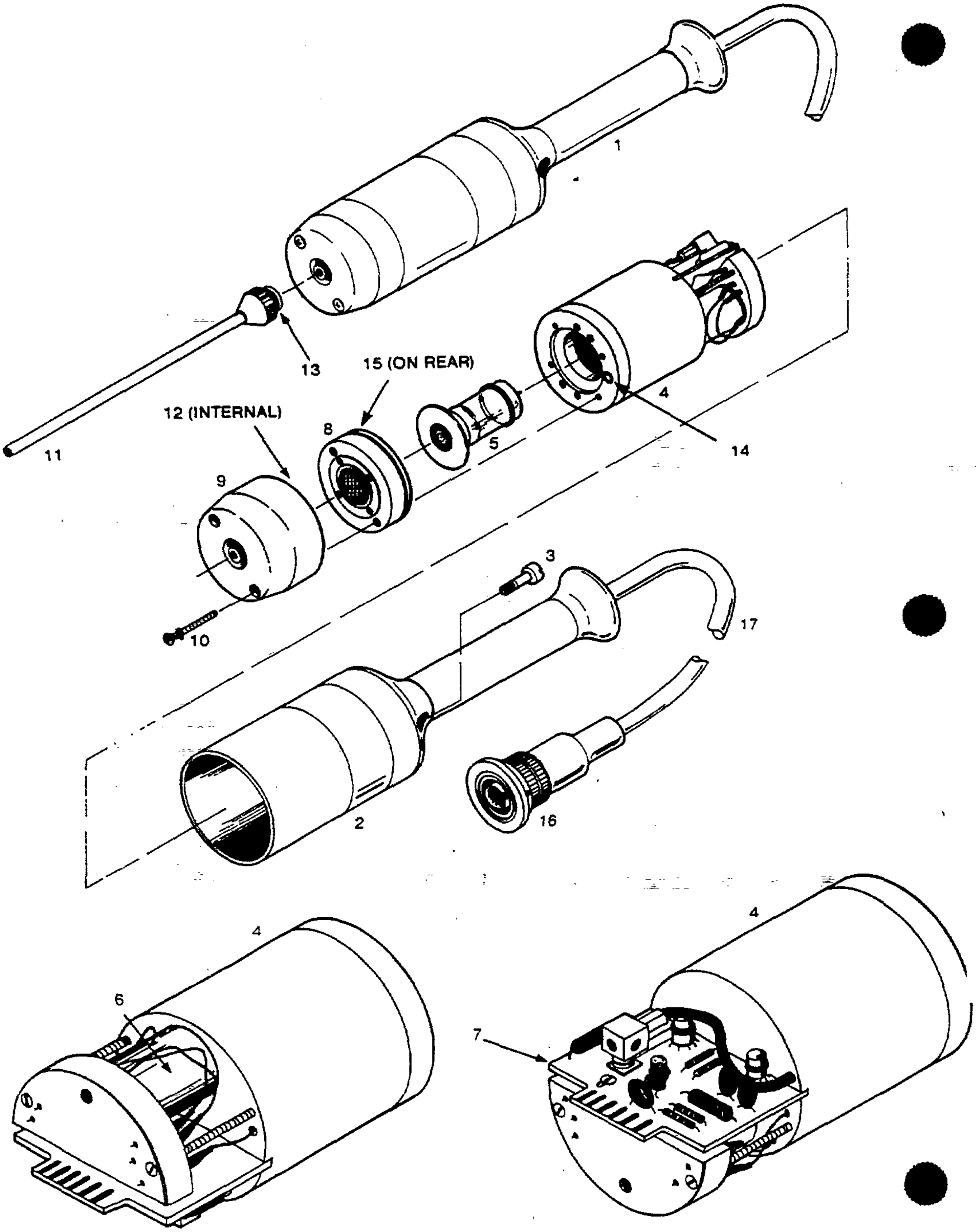

FIGURE 7-1

PARTS LOCATION, PROBE ASSEMBLY

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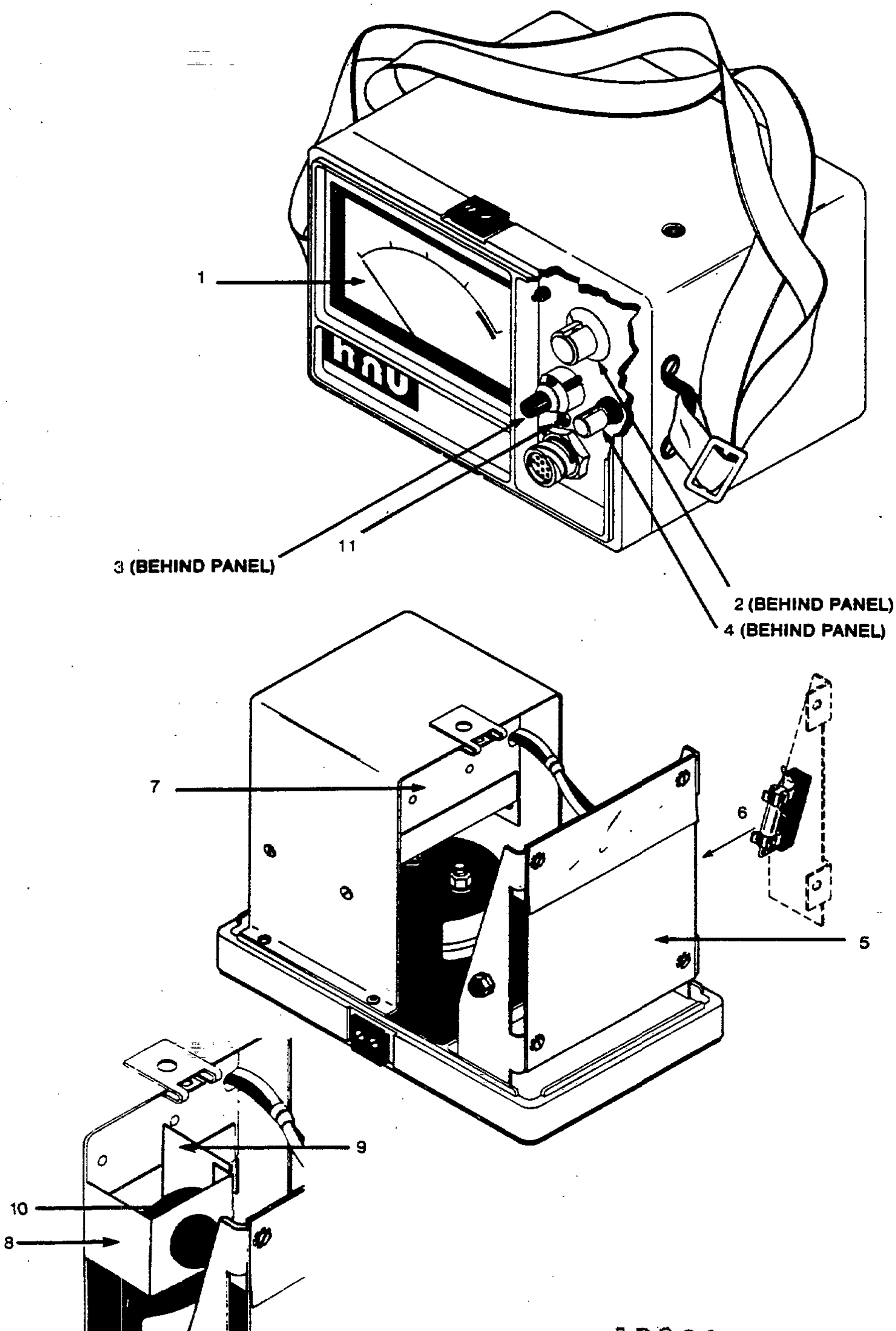

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FIGURE 7-2
PARTS LOCATION, READOUT ASSEMBLY

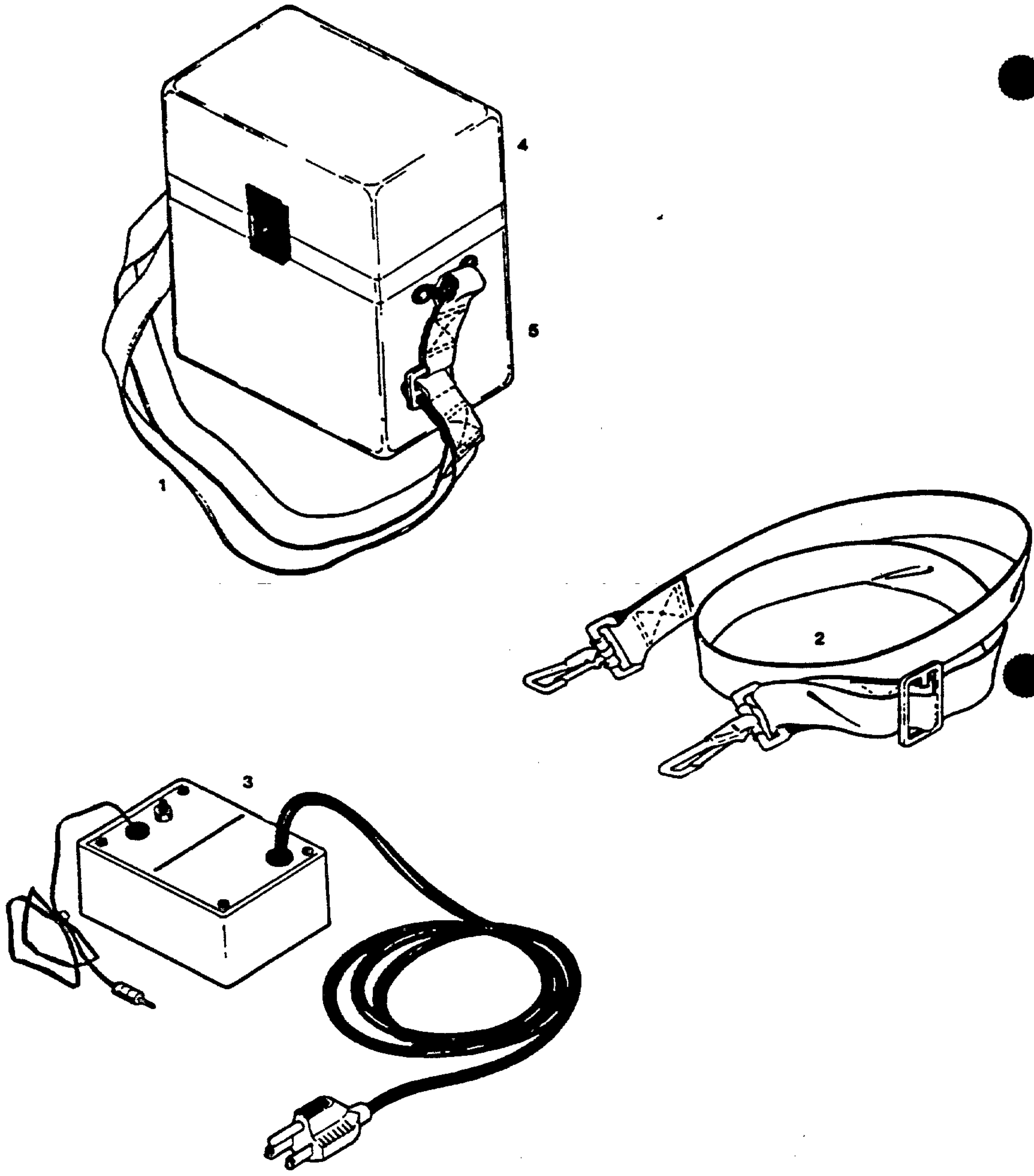

FIGURE 7-3
PARTS LOCATION, OTHER ITEMS

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ORIGINAL (Red)

SECTION 8

APPENDIX

This section contains the following additional information pertinent to the PI 101 Analyzer.

ORIGINAL (Red)

8.1 STATIC CALIBRATION

A technique known as static calibration is very useful when it is desired to calibrate with a particular special mixture rather than an available standard. The procedure is:

a. Select an inert container of known volume, e.g., a 4 liter Teflon bag, and clean by filling with hydrocarbon-free air and exhausting three or four times. The container and fittings should have minimal interaction with the gas to be used.

b. Fill the container with hydrocarbon-free air between samples and test with the analyzer. Repeat several times to determine the background level in the container. Correct instrument response by subtracting this background for accurate results.

c. Fill a small, inert gas-tight syringe (glass/Teflon) (e.g., 1 cc) with the desired gas and inject into the container. See the sample calculations. If the desired material is a liquid at room temperature, a smaller syringe (e.g., 1 ul or 10 ul) is used. Inject a known volume of the liquid into the container. Touch the syringe tip to the inside of the container to remove any residue droplets. A needle on the syringe is not necessary, but if one is used, it should be used throughout or delivery errors are possible.

d. Fill the container with a known volume of clean air and stopper the container. A large syringe, such as the Hamilton Model S1500 (1.5 liters) is recommended. Calibrated flowmeters may also be used. The accuracy of this calibration method is directly dependent on the accuracy used to measure the species involved.

e. Wait several minutes until the gas is well mixed or the liquid is evaporated and mixed. Check for liquid in the container before proceeding. If the liquid does not completely evaporate, the correct concentrations will not be seen in the gas phase. Warming the bag may be necessary to ensure complete evaporation.

f. Connect the probe inlet to the container making sure there are no leaks.
CAUTION: Work in a hood if hazardous gases are used.

WARNING

Be very careful to note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

ORIGINAL (Red)

g. Allow the analyzer to sample from the container. Compression of the container by hand may be necessary since the analyzer will not sample across a pressure drop. The analyzer flow is about 100 - 200 cc/min and small changes will not effect the reading. However, the flow should be constant.

h. Observe the readings during calibration to ensure that the gas is well mixed and there are no concentration gradients within the container. This will be evident by uniform meter readings.

i. Record the reading after about 10 seconds. The reading should be stable for up to 2 minutes since the flow rate is 100 to 200 cc/min. Large fluctuations in flow could effect the readings.

j. Adjust the SPAN control to set the analyzer to be direct reading at a concentration level near the range to be used.

k. Prepare 5 or 6 different concentrations of the calibration gas and plot the instrument readings versus concentration in ppm (v/v) to obtain a calibration curve. Clean the container between each point. For spot checking the calibration, two levels close to the measured concentration which agree to within 10% are acceptable. Concentrations lower than 100 ppm of a gas can be prepared by diluting a 100 or 200 ppm level with clean air. However, do not dilute a mixture by more than a factor of 10. A bias in the calibration curve could indicate preparation/container effects, such as "hang-up" on the walls of the container at high levels resulting in lower readings. At low levels, the compound may diffuse out or evaporate off the walls resulting in higher readings. Gentle heating should alleviate this condition.

ORIGINAL (Red)

STATIC CALIBRATION CALCULATIONS

GAS SAMPLING BAG

Precision: +/- 10%

Range: 20 ppm to 1 percent (see NOTE 1)

Sample Calculations:

Gaseous Sample: Assume 0.15 ml of a pure gas, e.g., vinyl chloride, is injected into the container with 1.5 liters of hydrocarbon-free air by the syringe. The concentration then is:

$$\frac{\text{volume injected (ml)}}{\text{vessel volume (ml)}} \times 10^6 = \frac{0.15\text{ ml}}{1500\text{ ml}} \times 10^6 = 100\text{ ppm}$$

Liquid sample: Assume 1.0 microliters of a volatile liquid such as toluene is injected into the container and 1.5 liter syringe filled with hydrocarbon-free air is added. The concentration then is:

$$\frac{\text{volume injected (ml)} \times \text{density (g/ml)} \times \text{molar volume (liters/mole)}}{\text{molecular weight (g/mole)} \times \text{volume of air (liters)}} \times 10^6$$

$$\frac{0.001\text{ ml} \times 0.87\text{ g/ml} \times 24.0\text{ liters/mole}}{92\text{ g/mole} \times 1.5\text{ liters}} = 10^6 = 151\text{ ppm (see NOTE 2)}$$

NOTES: 1. Larger gas and liquid syringes are needed for the upper portion of this range.

WARNING

Note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

2. The molar volume of toluene at 20 oC and one atmosphere is 24.0. This value must be corrected for the actual conditions, otherwise errors as high as 20% might be encountered. Corrections are made using the standard gas laws.

8.2 CALIBRATION CHECKING WITH ISOBUTYLENE

The calibration of the analyzer can be rapidly checked by the use of an HNU small disposable cylinder containing isobutylene (HNU pn 101-350) with a regulator (HNU pn 101-351).

At the factory, the analyzer is first calibrated on the desired gas standard at the specified concentration. Then a measurement is made with isobutylene.

The ppm reading along with the span setting using isobutylene is recorded in the calibration report.

In service, the analyzer calibration can be checked and readjusted if necessary by using this cylinder and regulator as follows:

a. Connect the analyzer to the regulator and cylinder with a short piece (butt connection) of tubing as shown in Figure 8-1. The calibration gas in the cylinder consists of a mixture of isobutylene and zero air. Isobutylene is nontoxic and safe to use in confined areas. There are no listed exposure levels at any concentration.
   The regulator sets and controls the flow rate of gas at a value preset at the factory. This will be about 250 cc/min.
   It is important that the tubing be clean since contaminated tubing will effect the calibration reading.
   Do not use the cylinder below about 30 psig as readings below that level can deviate up to 10% from the rated value.
   Safely discard the disposable cylinder when empty.
   Do not refill this cylinder.
   It is against the law to transport refilled cylinders.

b. With the SPAN setting and the function switch at the same positions as listed in the Application Data Sheet or Calibration Report, open the valve on the cylinder until a steady reading is obtained.

c. If the reading is the same as the recorded data, the analyzer calibration for the original species of interest is still correct.

d. If the reading has changed, adjust the SPAN setting until the reading is the same.

e. Shut off the cylinder as soon as the reading is established.

f. Record and maintain this new SPAN setting. Then recalibrate the analyzer on the species of interest as soon as possible.

g. Whenever the analyzer is recalibrated, it is to be immediately checked with the small cylinder and the reading recorded. This can then be used for later checking in the field.

ORIGINAL
(Red)

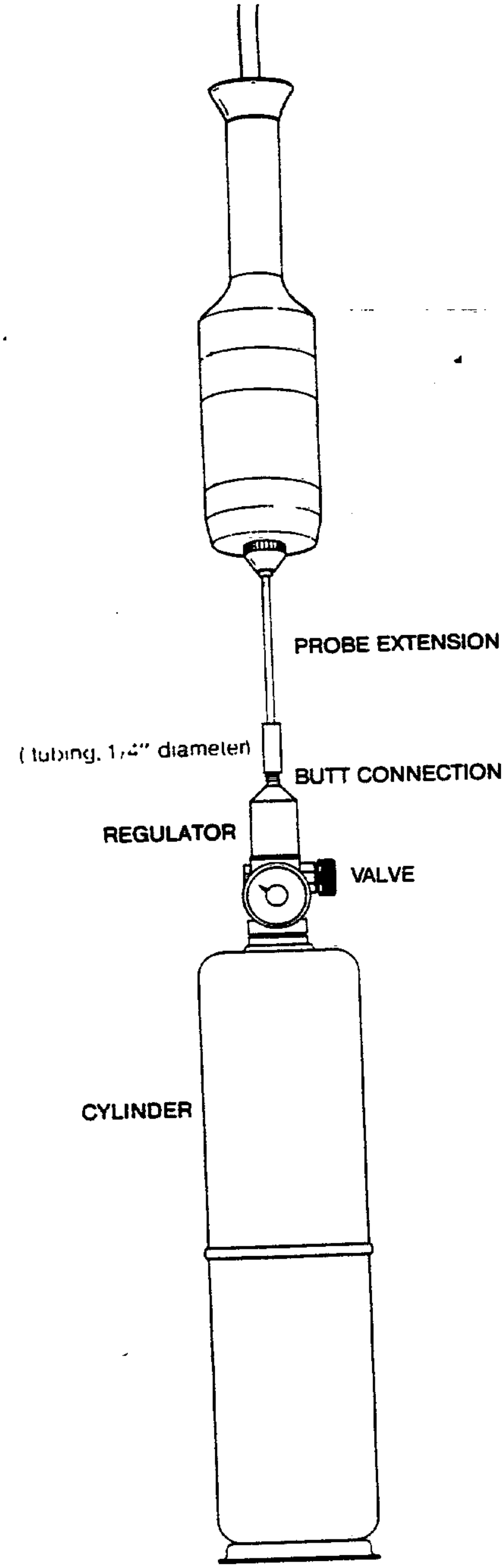

FIGURE 8-1
CALIBRATION CHECKING SET-UP

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8.3 CALIBRATION WITH ALTERNATE GAS

If a calibration standard with the same trace gas as that to be measured is not available or is hazardous, it is possible to use an alternate calibration gas. (Note : This technique may not be as accurate as calibration with the species of interest.) In this case, the expected reading for calibration must be compensated for the difference between the two gases. In operation, the meter will then give a direct reading of the gas being measured.

This calibration is illustrated in the following examples: (PS = Photoionization Sensitivity. See Table 8-14)

a. Given a case in which:

1) The trace gas to be measured is Vinyl Chloride (PS = 5.0)

2) The calibration gas to be used is Isobutylene (PS = 7.0) at a 100 ppm level

What is the ppm reading to be when calibrating to give a direct reading when measuring Vinyl Chloride?

The required reading for calibration will be:

$$= \text{Isobutylene ppm} \times \frac{\text{PS(Isob)}}{\text{PS(Vin Chlor)}}$$

$$= 100 \times \frac{7.0}{5.0}$$

40%

$$= 140 \text{ ppm}$$

In this example, using a calibration gas with 100 ppm of Isobutylene, adjust the SPAN control so the meter reads 140 ppm. In operation, the instrument will then give a direct reading of the ppm of Vinyl Chloride.

b. Given a case in which:

1) The trace gas to be measured is Benzene (PS = 10.0)

2) The calibration gas to be used is Isobutylene (PS = 7.0) at a level of 100 ppm

3) What is the ppm reading to be when calibrating to give a direct reading when measuring Benzene.

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The required reading for calibration will be:

$$= \text{Isobutylene ppm} \times \frac{PS(Isob)}{PS(Benzene)}$$

$$= 100 \times \frac{7.0}{10.0}$$

$$= 70.0 \text{ ppm}$$

In this example, using a calibration gas with 100 ppm of Isobutylene, adjust the SPAN control so the meter reads 70 ppm. In operation, the instrument will then give a direct reading of the ppm of Benzene.

c. Given a case in which:

1) The trace gas to be measured is H_2S (PS = 2.8)

2) The level of H_2S for which it is to be calibrated is 60 ppm.

3) The calibration gas available is Isobutylene (PS = 7.0)

4) What ppm level of Isobutylene is required to permit direct reading of H_2S, calibrating at its 60 ppm level.

The required Isobutylene level for calibration will be:

$$= H_2S \text{ ppm} \times \frac{PS(H_2S)}{PS(Isob)}$$

$$= 60 \times \frac{2.8}{7.0}$$

$$= 24.0 \text{ ppm}$$

In this example, using a calibration gas with 24.0 ppm of Isobutylene, adjust the SPAN control so the meter reads 60 ppm. In operation, the instrument will then give a direct reading of the ppm of H_2S.

Care is to be taken when working with flammable gas samples to stay below the Lower Explosive Limit (LEL) and with hazardous or toxic gases to stay below the Threshold Limit Value (TLV) safe working level.

If difficulties are encountered in calibration, the user should consult the local HNU representative.

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8.4 UNCALIBRATED OPERATION

Best operation of the analyzer is accomplished by its calibration for the gas to be measured. In cases where it becomes necessary to operate with a gas for which it has not been calibrated and recalibration is not possible, correction can be made to the meter reading.

One method is by use of a chart. Figure 8-2 is such a chart. It shows performance curves for various gases being measured by an instrument with a 10.2 eV lamp and calibrated for benzene. This illustrates the effect of the different sensitivities of gases. These curves can be used directly for correcting a meter reading if the instrument is calibrated for benzene and is measuring one of the gases shown. For example, if the gas being measured is Propylene and the reading is 8 ppm, then the actual concentration is about 20 ppm.

A second method is to multiply the meter reading by a correction factor as follows:

$$\text{Actual ppm} = \text{ppm reading} \times \frac{\text{PS (Cal gas)}}{\text{PS (Trace gas)}}$$

in which

PS is the photoionization sensitivity of each of the two gases. Table 8-14 gives a list of the relative photoionization sensitivities of a number of specific gases with which the analyzer might be used. Use of this method is illustrated by the following examples:

a. Instrument calibrated for Benzene (PS = 10.0) and measuring Acetone (PS = 6.3)

$$\text{Actual ppm} = \text{ppm reading} \times \frac{10.0}{6.3}$$

$$= \text{ppm reading} \times 1.6$$

b. Instrument calibrated for Vinyl Chloride (PS = 5.0) and measuring Carbon Disulfide (PS = 7.1)

$$\text{Actual ppm} = \text{ppm reading} \times \frac{5.0}{7.1}$$

$$= \text{ppm reading} \times 0.7$$

These values are valid only for an analyzer with a 10.2 eV lamp. Different sensitivities occur with 9.5 and 11.7 eV lamps.

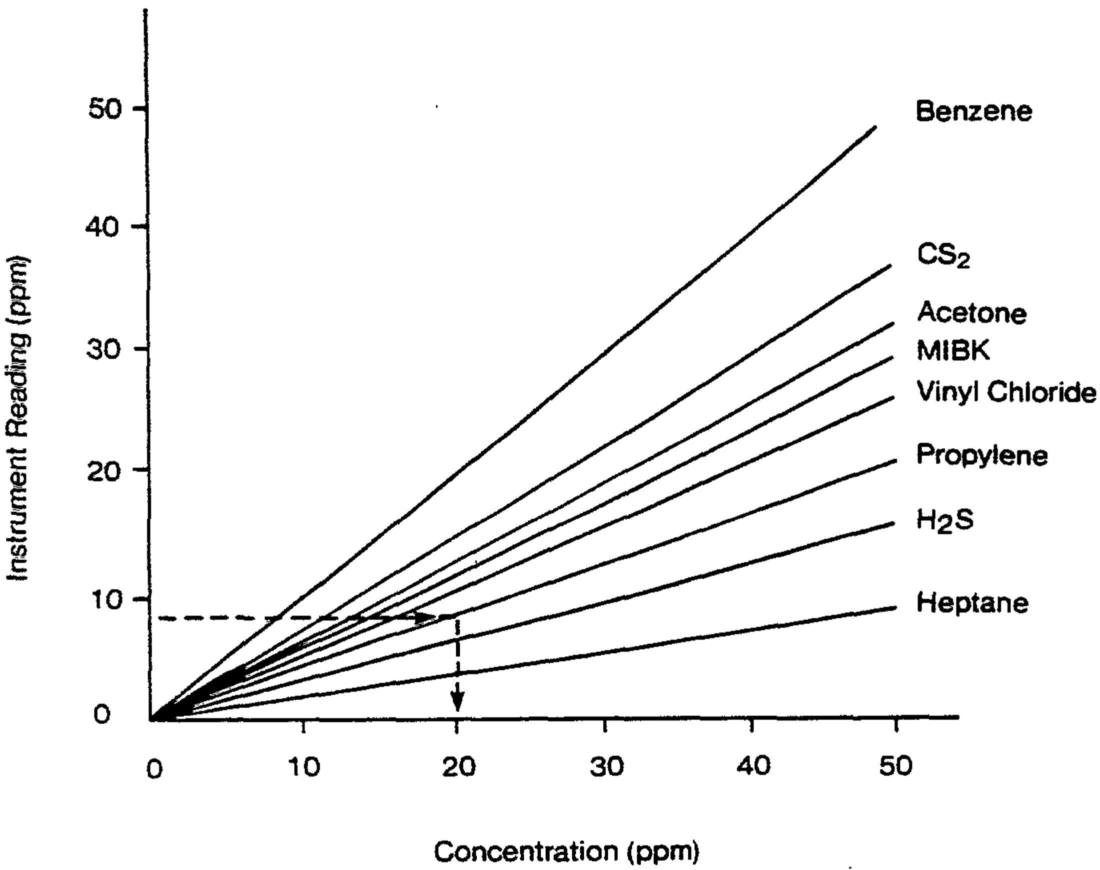

FIGURE 8-2
TYPICAL OUTPUT CURVES – ANALYZER WITH 10.2 eV LAMP CALIBRATED FOR BENZENE

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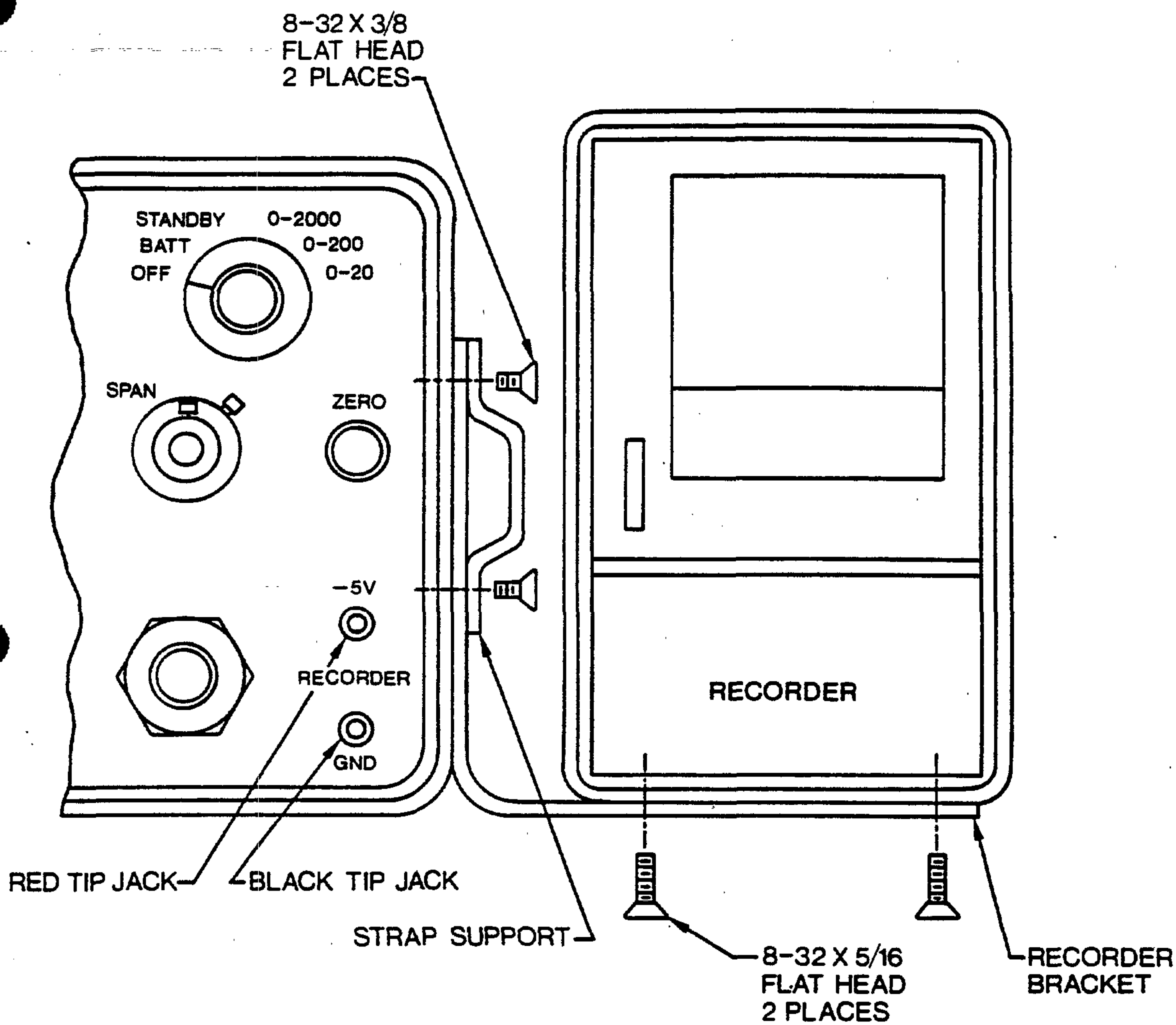

FIGURE 8-3
RECORDER MOUNTING

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ˀ.5 Ionization Tables

Ionization potentials for various atoms, molecules, and compounds are given in Tables 8-1 thru 8-13. Ionization sensitivities and approximate span settings for 10.2 eV, 11.7 eV, and 9.5 eV lamps are given in Tables 8-14, 8-15, and 8-16 respectively.

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TABLE 8.1

SOME ATOMS AND SIMPLE MOLECULES

	IP (eV)		IP (eV)
H	13.595	I_2	9.28
C	11.264	HF	15.77
N	14.54	HCl	12.74
O	13.614	HBr	11.62
Si	8.149	HI	10.38
S	10.357	SO_2	12.34
F	17.42	CO_2	13.79
Cl	13.01	COS	11.18
Br	11.84	CS_2	10.08
I	10.48	N_2O	12.90
H_2	15.426	NO_2	9.78
N_2	15.580	O_3	12.80
O_2	12.075	H_2O	12.59
CO	14.01	H_2S	10.46
CN	15.13	H_2Se	9.88
NO	9.25	H_2Te	9.14
CH	11.1	HCN	13.91
OH	13.18	C_2N_2	13.8
F_2	15.7	NH_3	10.15
Cl_2	11.48	CH_3	9.840
Br_2	10.55	CH_4	12.98

TABLE 8.2

PARAFFINS AND CYCLOPARAFFINS

Molecule	IP (eV)
methane	12.98
ethane	11.65
propane	11.07
n-butane	10.63
i-butane	10.57
n-pentane	10.35
i-pentane	10.32
2, 2-dimethylpropane	10.35
n-hexane	10.18
2-methylpentane	10.12
3-methylpentane	10.08
2, 2-dimethylbutane	10.06
2, 3-dimethylbutane	10.02
n-heptane	10.08
2,2,4-trimethylpentane	9.86
cyclopropane	10.06
cyclopentane	10.53
cyclohexane	9.88
methylcyclohexane	9.85

TABLE 8.3

ALKYL HALIDES

Molecule	IP (eV)
HCl	12.74
Cl_2	11.48
CH_4	12.98
methyl chloride	11.28
dichloromethane	11.35
trichloromethane	11.42
tetrachloromethane	11.47
ethyl chloride	10.98
1,2-dichloroethane	11.12
1-chloropropane	10.82
2-chloropropane	10.78
1,2-dichloropropane	10.87
1,3-dichloropropane	10.85
1-chlorobutane	10.67
2-chlorobutane	10.65
1-chloro-2-methylpropane	10.66
2-chloro-2-methylpropane	10.61
HBr	11.62
Br_2	10.55
methyl bromide	10.53
dibromomethane	10.49
tribomomethane	10.51
CH_2BrCl	10.77
$CHBr_2Cl$	10.59
ethyl bromide	10.29
1,1-dibromoethane	10.19
1-bromo-2-chloroethane	10.63

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TABLE 8.3 (continued)

Molecule	IP (eV)
1-bromopropane	10.18
2-bromopropane	10.075
1,3-dibromopropane	10.07
1-bromobutane	10.13
2-bromobutane	9.98
1-bromo-2-methylpropane	10.09
2-bromo-2-methylpropane	9.89
1-bromopentane	10.10
HI	10.38
I_2	9.28
methyl iodide	9.54
diiodomethane	9.34
ethyl iodide	9.33
1-iodopropane	9.26
2-iodopropane	9.17
1-iodobutane	9.21
2-iodobutane	9.09
1-iodo-2-methylpropane	9.18
2-iodo-2-methylpropane	9.02
1-iodopentane	9.19
F_2	15.7
HF	15.77
$CFCl_3$ (Freon 11)	11.77
CF_2Cl_2(Freon 12)	12.31
CF_3Cl (Freon 13)	12.91
$CHClF_2$ (Freon 22)	12.45
$CFBr_3$	10.67

ORIGINAL (Red)

TABLE 8.3 (continued)

Molecule	IP (eV)
CF_2Br_2	11.07
CH_3CF_2Cl (Genetron 101)	11.98
$CFCl_2CF_2Cl$	11.99
CF_3CCl_3 (Freon 113)	11.78
$CFHBrCH_2Br$	10.75
CF_2BrCH_2Br	10.83
CF_3CH_2I	10.00
n-C_3F_7I	10.36
n-$C_3F_7CH_2Cl$	11.84
n-$C_3F_7CH_2I$	9.96

TABLE 8.4

ALIPHATIC ALCOHOL, ETHER, THIOL, AND SULFIDES

Molecule	IP (eV)
H_2O	12.59
methyl alcohol	10.85
ethyl alcohol	10.48
n-propyl alcohol	10.20
i-propyl alcohol	10.16
n-butyl alcohol	10.04
dimethyl ether	10.00
diethyl ether	9.53
n-propyl ether	9.27
i-propyl ether	9.20
H_2S	10.46
methanethiol	9.440
ethanethiol	9.285
1-propanethiol	9.195
1-butanethiol	9.14
dimethyl sulfide	8.685
ethyl methyl sulfide	8.55
diethyl sulfide	8.430
di-n-propyl sulfide	8.30

TABLE 8.5

ALIPHATIC ALDEHYDES AND KETONES

Molecule	IP (eV)
CO_2	13.79
formaldehyde	10.87
acetaldehyde	10.21
propionaldehyde	9.98
n-butyraldehyde	9.86
isobutyraldehyde	9.74
n-valeraldehyde	9.82
isovaleraldehyde	9.71
acrolein	10.10
crotonaldehyde	9.73
benzaldehyde	9.53
acetone	9.69
methyl ethyl ketone	9.53
methyl n-propyl ketone	9.39
methyl i-propyl ketone	9.32
diethyl ketone	9.32
methyl n-butyl ketone	9.34
methyl i-butyl ketone	9.30
3, 3-dimethyl butanone	9.17
2-heptanone	9.33
cyclopentanone	9.26
cyclohexanone	9.14
2, 3-butanedione	9.23
2, 4-pentanedione	8.87

TABLE 8.6

ALIPHATIC ACIDS AND ESTERS

Molecule	IP (eV)
CO_2	13.79
formic acid	11.05
acetic acid	10.37
propionic acid	10.24
n-butyric acid	10.16
isobutyric acid	10.02
n-valeric acid	10.12
methyl formate	10.815
ethyl formate	10.61
n-propyl formate	10.54
n-butyl formate	10.50
isobutyl formate	10.46
methyl acetate	10.27
ethyl acetate	10.11
n-propyl acetate	10.04
isopropyl acetate	9.99
n-butyl acetate	10.01
isobutyl acetate	9.97
sec-butyl acetate	9.91
methyl propionate	10.15
ethyl propionate	10.00
methyl n-butyrate	10.07
methyl isobutyrate	9.98

TABLE 8.7

ALIPHATIC AMINES AND AMIDES

Molecule	IP (eV)
NH_3	10.15
methyl amine	8.97
ethyl amine	8.86
n-propyl amine	8.78
i-propyl amine	8.72
n-butyl amine	8.71
i-butyl amine	8.70
s-butyl amine	8.70
t-butyl amine	8.64
dimethyl amine	8.24
diethyl amine	8.01
di-n-propyl amine	7.84
di-i-propyl amine	7.73
di-n-butyl amine	7.69
trimethyl amine	7.82
triethyl amine	7.50
tri-n-propyl amine	7.23
formamide	10.25
acetamide	9.77
N-methyl acetamide	8.90
N,N-dimethyl formamide	9.12
N,N-dimethyl acetamide	8.81
N,N-diethyl formamide	8.89
N,N-diethyl acetamide	8.60

TABLE 8.8

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OTHER ALIPHATIC MOLECULES WITH N ATOM

Molecule	IP (eV)
nitromethane	11.08
nitroethane	10.88
1-nitropropane	10.81
2-nitropropane	10.71
HCN	13.91
acetonitrile	12.22
propionitrile	11.84
n-butyronitrile	11.67
acrylonitrile	10.91
3-butene-nitrile	10.39
ethyl nitrate	11.22
n-propyl nitrate	
methyl thiocyanate	10.065
ethyl thiocyanate	9.89
methyl isothiocyanate	9.25
ethyl isothiocyanate	9.14

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TABLE 8.9

OLEFINS, CYCLO-OLEFINS, ACETYLENES

Molecule	IP (eV)
ethylene	10.515
propylene	9.73
1-butene	9.58
2-methylpropene	9.23
trans-2-butene	9.13
cis-2-butene	9.13
1-pentene	9.50
2-methyl-1-butene	9.12
3-methyl-1-butene	9.51
3-methyl-2-butene	8.67
1-hexene	9.46
1,3-butadiene	9.07
isoprene	8.845
cyclopentene	9.01
cyclohexene	8.945
4-methylcyclohexene	8.91
4-cinylcylohexene	8.93
cyclo-octatetraene	7.99
acetylene	11.41
propyne	10.36
1-butyne	10.18

TABLE 8.10

SOME DERIVATIVES OF OLEFINS

Molecule	IP (eV)
vinyl chloride	9.995
cis-dichloroethylene	9.65
trans-dichloroethylene	9.66
trichloroethylene	9.45
tetrachloroethylene	9.32
vinyl bromide	9.80
1,2-dibromoethylene	9.45
tribromoethylene	9.27
3-chloropropene	10.04
2,3-dichloropropene	9.82
1-bromopropene	9.30
3-bromopropene	9.7
$CF_3CCl{=}CClCF_3$	10.36
n-$C_5F_{11}CF{=}CF_2$	10.48
acrolein	10.10
crotonaldehyde	9.73
mesityl oxide	9.08
vinyl methyl ether	8.93
allyl alcohol	9.67
vinyl acetate	9.19

TABLE 8.11

HETEROCYCLIC MOLECULES

Molecule	IP (eV)
furan	8.89
2-methyl furan	8.39
2-furaldehyde	9.21
tetrahydrofuran	9.54
dihydropyran	8.34
tetrahydropyran	9.26
thiophene	8.860
2-chlorothiophene	8.68
2-bromothiophene	8.63
pyrrole	8.20
pyridine	9.32
2-picoline	9.02
3-picoline	9.04
4-picoline	9.04
2,3-lutidine	8.85
2,4-lutidine	8.85
2,6-lutidine	8.85

TABLE 8.12

AROMATIC COMPOUNDS

Molecule	IP (eV)
benzene	9.245
toluene	8.82
ethyl benzene	8.76
n-propyl benzene	8.72
i-propyl benzene	8.69
n-butyl benzene	8.69
s-butyl benzene	8.68
t-butyl benzene	8.68
o-xylene	8.56
m-xylene	8.56
p-xylene	8.445
mesitylene	8.40
durene	8.025
styrene	8.47
α-methyl styrene	8.35
ethynylbenzene	8.815
napthalene	8.12
1-methylnapthalene	7.69
2-methylnapthalene	7.955
biphenyl	8.27
phenol	8.50
anisole	8.22
phenetole	8.13
benzaldehyde	9.53
acetophenone	9.27
benzenethiol	8.33
phenyl isocyanate	8.77

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TABLE 8.12 (continued)

Molecule	IP (eV)
phenyl isothiocyanate	8.520
benzonitrile	9.705
nitrobenzene	9.92
aniline	7.70
fluoro-benzene	9.195
chloro-benzene	9.07
bromo-benzene	8.98
iodo-benzene	8.73
o-dichlorobenzene	9.07
m-dichlorobenzene	9.12
p-dichlorobenzene	8.94
1-chloro-2-fluorobenzene	9.155
1-chloro-3-fluorobenzene	9.21
1-bromo-4-fluorobenzene	8.99
o-fluorotoluene	8.915
m-fluorotoluene	8.915
p-fluorotoluene	8.785
o-chlorotoluene	8.83
m-chlorotoluene	8.83
p-chlorotoluene	8.70
o-bromotoluene	8.79
m-bromotoluene	8.81
p-bromotoluene	8.67
o-iodotoluene	8.62
m-iodotoluene	8.61
p-iodotoluene	8.50
benzotrifluoride	9.68
o-fluorophenol	8.66

TABLE 8.13

MISCELLANEOUS MOLECULES

Molecule	IP (eV)
ethylene oxide	10.565
propylene oxide	10.22
p-dioxane	9.13
dimethoxymethane	10.00
diethoxymethane	9.70
1,1-dimethoxyethane	9.65
propiolactone	9.70
methyl disulfide	8.46
ethyl disulfide	8.27
diethyl sulfite	9.68
thiolacetic acid	10.00
acetyl chloride	11.02
acetyl bromide	10.55
cyclo-$C_6H_{11}CF_3$	10.46
$(n\text{-}C_3F_7)(CH_3)C{=}O$	10.58
trichlorovinylsilane	10.79
$(C_2F_5)_3N$	11.7
isoprene	9.08
phosgene	11.77

TABLE 8-14

RELATIVE PHOTOIONIZATION SENSITIVITIES OF VARIOUS GASES TO A 10.2 eV LAMP

Gas	Photoionization Sensitivity (see Note 1)	Span Control Setting for Direct reading (approximate)
p-xylene	11.4	
m-xylene	11.2	
benzene	10.0 (reference standard)	9.8
toluene	10.0	
diethyl sulfide	10.0	
diethyl amine	9.9	
styrene	9.7	
trichloroethylene	8.9	8.2
carbon disulfide	7.1	
isobutylene	7.0	
acetone	6.3	
tetrahydrofuran	6.0	5.5
methyl ethyl ketone	5.7	
methyl isobutyl ketone	5.7	
cyclohexanone	5.1	
naptha (85% aromatics)	5.0	
vinyl chloride	5.0	4.3
methyl isocyanate	4.5	
iodine	4.5	
methyl mercaptan	4.3	

TABLE 8-14 cont.

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dimethyl sulfide	4.3	
allyl alcohol	4.2	
propylene	4.0	3.5
mineral spirits	4.0	
2, 3-dichloropropene	4.0	
cycloexene	3.4	
crotonaldehyde	3.1	
acrolein	3.1	
methyl methacrylate	3.0	2.4
pyridine	3.0	
hydrogen sulfide	2.8	
ethylene dibromide	2.7	1.9
n-octane	2.5	
acetaldehyde oxime	2.3	
hexane	2.2	
phosphine	2.0	
heptane	1.7	
allyl chloride (3-chloropropene)	1.5	
ethylene	1.0	
isopropanol	1.0	0.1
ethylene oxide	1.0	
acetic anhydride	1.0	
alpha pinene	0.7	
dibromochloropropane	0.7	

epichlorohydrin	0.7
nitric oxide	0.6
beta pinene	0.5
citral	0.5
ammonia	0.3
acetic acid	0.1
nitrogen dioxide	0.02
methane	0.0
acetylene	0.0

NOTE 1: PPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

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TABLE 8-15

RELATIVE PHOTOIONIZATION SENSITIVITIES OF VARIOUS GASES TO A 11.7 eV LAMP

Direct Gas (Approx.)	Photoionization Sensitivity (See Note 1)	Span Control Setting for Direct Reading (Approx.)
Carbon Disulfide	33.8	
Heptane	22.1	
Hexane	18.9	
Pentane	14.1	
1,2 Dichloroethane	12.9	
Benzene	12.2	5.0
MIBK	10.6	
Isobutylene	10.0 (Reference Std.)	
Toluene	10.0	
Methyl Chloride	9.8	
Methylene Chloride	9.4	
111 Trichloroethane	9.0	
Carbon Tetrachloride	9.0	
Ethylene Dichloride	9.0	
Butane	8.7	
THF	7.9	
Acrylonitrile	7.1	2.0
MEK	6.3	
Chloroform	6.0	
1,1,2,2 Tetrachloroethane	6.0	
Acetone	5.7	
Propane	5.5	
Isopropoponol	4.5	
Acrolein	3.4	1.0
Ethane	3.0	
Ethanol	3.0	
Methanol	1.0	
1,1,2 Trifluoroethane	0.3	
Acetonitrile	0.1	

NOTE 1: PPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

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TABLE 8-16

RELATIVE PHOTOIONIZATION SENSITIVITIES

OF VARIOUS GASES TO A 9.5 eV LAMP

Direct Gas (Approx.)	Photoionization Sensitivity (See Note 1)	Span Control Setting for Direct Reading (Approx.)
Xylene	11.2	
Benzene	10.0 (Reference Std.)	1.0
Styrene	10.0	
Toluene	10.0	
Phenol	7.7	
Aniline	3.9	
MEK	2.9	
Pyridine	2.2	
Acetone	0.65	
Methyl Methacrylate	<0.6*	
Heptane	<0.2*	
Hexane	0	
Ammonia	0	
Pentane	0	

* Commercial products containing impurities; response for pure materials is probably less.

NOTE 1: PPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

8.7 WARRANTY

HNU Systems, Incorporated, warrants all items to be free from defects in material and workmanship when used under normal operating conditions. HNU's liability hereunder shall be limited to the repair or replacement of the articles ascertained to be defective within one (1) year after date of shipment (except that the light source warranty is limited to three (3) months and does not include breakage, and battery warranty is limited to three (3) months), provided, however that the Buyer shall give notice to HNU within thirty (30) days after discovery of such defective material and provided further that all defective material be shipped prepaid to the HNU plant within a reasonable time from the date of discovery of the defect and during such warranty period. After the repair or replacement, HNU will ship the said item to Buyer, transportation charges prepaid, to any point in the United States that Buyer may designate.

THE FOREGOING IS THE SOLE EXTENT OF HNU'S WARRANTY AND NO OTHER STATEMENTS OR WARRANTIES, EXPRESSED OR IMPLIED, SHALL BE HONORED. UNDER NO CIRCUMSTANCES SHALL HNU BE SUBJECT TO ANY LIABILITY FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES.

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8.8 Publications on Photoionization Available from HNU Systems, Inc.

101-10 Industrial Hygiene Monitoring With A Variable Selectivity Photoionization Analyzer.
J.N. Driscoll and J.H. Becker,
American Laboratory, November 1979.

101-12 Instrumentation for "On Site" Survey and Identification of Hazardous Waste.
J.N. Driscoll and G.F. Hewitt,
Industrial Hygiene News, May 1982

101-17 Instrument Calibration with Toxic and Hazardous Materials.
J.H. Becker, J.N. Driscoll, D. Renaud, P. Tiffany, C. Sylvia,
Industrial Hygiene News, July 1983.
